Public Relations

FOR

INDUSTRY

WITH SPECIAL REFERENCE TO THE ENGINEERING FIELD

A Presentation of the Imperative Need of Mutual Understanding in the Conduct of Our Daily Work

PRESENTED BY PRODUCT ENGINEERING

October, 1938

An Editorial Service to Meet

INDUSTRY'S MAJOR PROBLEM

To the readers of Product Engineering

THERE IS NO DOUBT that today the American people are taking a keener, more critical interest in the conduct of business than ever before. And when I say critical, I mean exactly that. During recent years most of them have suffered loss, either of jobs or of savings, and under such circumstances men are prone to accept without serious question any scapegoat that appears plausible. In the confusion of fears and resentments, they seem to have concluded that short sighted and selfish business management is chiefly responsible for their misfortune.

However mistaken and unfair such conclusions may be, management cannot ignore them. It must recognize that in the long run, the opinions of men are the result of experience, of what happens to them each day, much more than of what they are told.

Progressive management has already faced that fact; has already begun to think and work beyond the technicalities of production and distribution that once absorbed most of its energies. It sees more clearly and deals more proficiently with its human responsibilities. It is learning to reconcile the economic success of the industrial unit with the social welfare of worker and community.

Presently, every business—the small retailer as well as the large manufacturer—must learn how to interpret more convincingly to its own public the social as well as the economic benefits of its policies and accomplishments. Only as such business satisfies the newly aroused and critical interest of people in its affairs will it be able to disarm those who trade on the human tendency to blame our troubles on someone else. Yes, if business as a whole is to win a favorable public opinion, each and every business must act to improve its own public relations.

The readers of this journal, and of other business publications, compose, we believe, a group that can achieve for American business a sound and lasting solution of this vital problem. They alone are in position to shape the working conditions of 21 million employees. They alone can mould the attitude of those other millions who compose the various "publics" to which all business must be responsible.

Heretofore, the function of business papers has been to exchange successful experience; to dig up and disseminate practical facts for the use of their readers, serving primarily the technical and merchandising needs of business. But this matter of human relations has now become of equal importance, for good industrial and public relations, it has been found, reduces corporate losses, removes fear and suspicion, promotes operating efficiencies in both production and sales. A better knowledge of public relations technique is, therefore, quite properly essential for men in, or moving into, positions of greater executive responsibility.

So, beginning with this insert, each McGraw-Hill publication sets out to strengthen its editorial service in the important domain of Public Relations. I hope that the million readers of McGraw-Hill's business papers will get much real and practical help toward building better relationships between their own businesses and their employees, their customers, and the communities in which they must carry on.

James H. McGraw Jr.

President, McGraw-Hill Publishing Co., Inc.

Why a Public Relations Program

In less than two generations the United States has changed from an agricultural to an industrial nation. Living standards and efficiencies at once the despair and envy of other countries have been created. Foreign delegations still flock to our shores to study our methods so that they may use them as patterns for their own organizations. Yet here at home today these methods and the systems responsible for them are under increasing attack.

Since every person employed in productive enterprise is a part of American industry, these attacks imperil the livelihood of nearly forty million workers and their dependents. The newest addition to the payroll has as much, if not more, at stake as the veteran business executive. That also is true of particular industries which at present may not be under direct fire. All industry is so interrelated and interdependent that even the seemingly immune enterprise must suffer when the legitimate activities and the buying power of their customers, or the customers of their customers, are curtailed.

Ironically enough, public acquiescence in many of the current attacks is an indirect recognition of the satisfactory manner in which our industrial system normally functions. Reasonable opportunities for the employment of those ambitions to put their mental or physical talents to work, and continually rising standards of living have come to be widely accepted as a matter of course. Any unfavorable change in these conditions leaves the general public surprised, confused and resentful. Such reactions as these make it easy for pressure groups to unloose destructive propaganda which further heightens resentments and breeds new misconceptions.

These misconceptions take many forms shaped by the experience, the inexperience, or the special interests of the critics. To one it appears that business can't manage itself and must be owned and managed by the Government. Another believes that employees are underpaid or that stockholders and executives are overpaid. To others corporate surpluses are too high. Many have convinced themselves that power and machines have reduced employment opportunities; and that industry can raise wages and reduce prices while costs go up.

Several misconceptions are based on faulty generalizations. Because a few companies have been remarkably successful, it is argued that all could make money. Because some corporations have been ruthless, all corporations, it is contended, will stoop to unethical conduct to gain their ends. This is like saying: John Smith killed Bill Brown; John Smith is auburn-thatched; all redheads, therefore, are murderers. Unfortunately, those who would indict all business for the crimes of a few are more subtle in their approach and so create an impression not in accord with the facts.

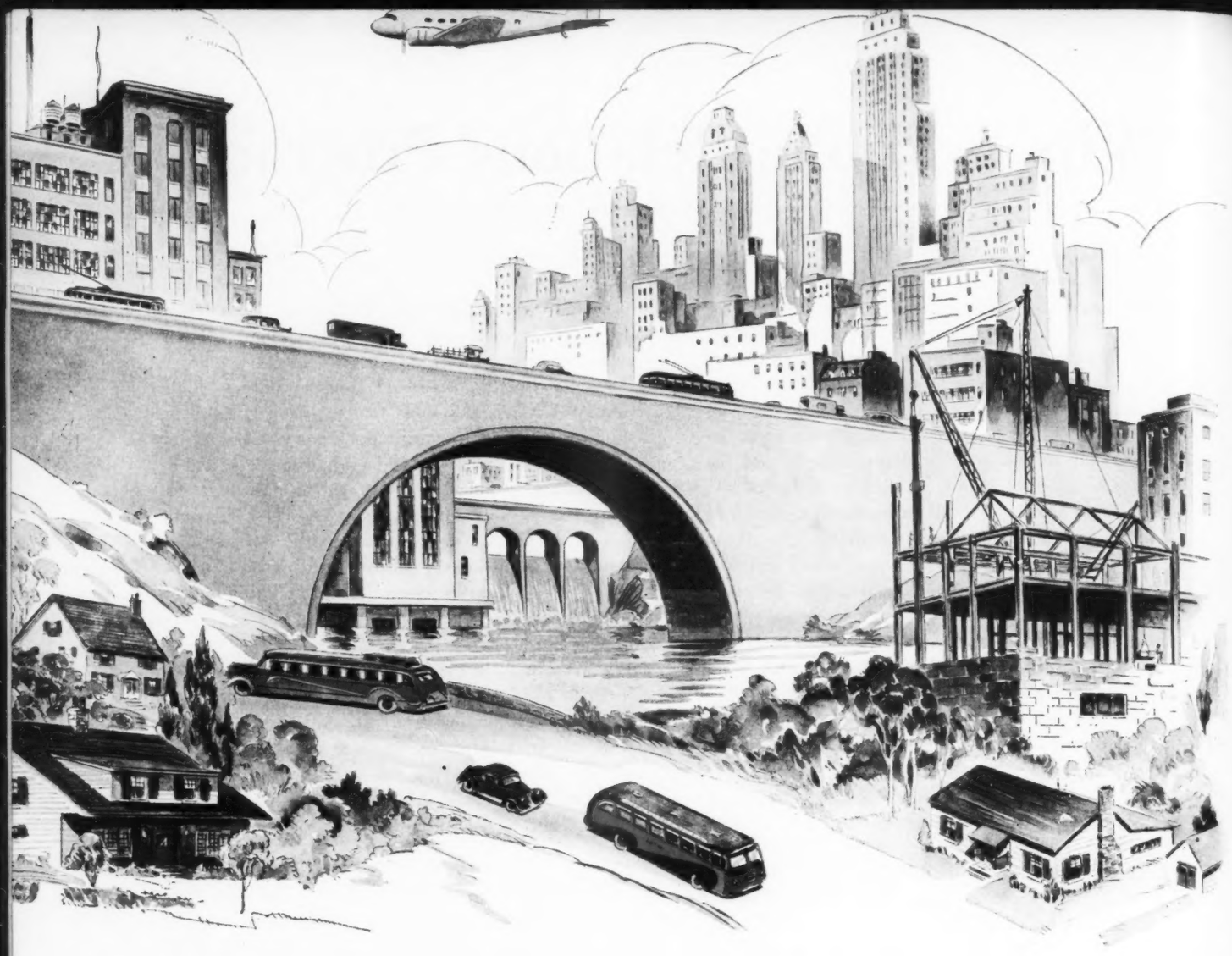
To put it bluntly, American industry, once so highly praised for its contributions to the national well-being, is now on the spot. Prevailing misconceptions of how business operates, and what it does, have made a field day for those who propose to hamstring or destroy private initiative and individual opportunity. These proposals run a broad gamut: They include public ownership, increasing and rigid federal control at the expense of local autonomy, ill-conceived legislation on hours and wages, labor dictatorships, and confiscatory taxes on thrift and employment security.

While the man in the street may be criticized for his willingness to swallow these nostrums, he is not wholly to blame. Industry, too, has been at fault, in assuming either that he was fully informed on those phases of its operations which are properly a matter of public interest, or that a healthy curiosity should be discouraged. Misconceptions multiply where the facts are hidden.

The tragedy of the situation lies in the fact that it might easily have been avoided. In the simple days of local and localized industry, everybody connected with a particular enterprise knew everybody else connected with it, and the details of its operations were an open book. The boss and the employees were neighbors; the customers, for the most part, fellow townsmen. Outside purchases were limited largely to those products which the local community neither manufactured nor raised. Competition in the modern sense was practically non-existent.

As industry developed and enlarged its field of operations, much of this early intimate personal touch was lost. The small enterprise grew bigger. In some cases combinations took in the local business and financial control passed out of the community. The local industry which still retained its identity was busy meeting increased competition and seeking to expand its distribution. Little attention was paid to changing conditions that were fostering misconceptions about the personal relations of the business. Bit by bit the close acquaintance and familiarity of the early days disappeared.

Common understanding of these things also was impeded by the greater variety of occupations as industry expanded. Each man's job became so highly specialized that the old feeling of common partnership in a joint undertaking frequently was buried in an exaggerated feel-



ing of the relative importance of his own work. This made it easy for each occupational group to get the idea that its contribution to the undertaking alone was essential and that many of the other groups were parasitic or, at best unimportant.

Such mistaken beliefs are the exclusive property of no particular group. "Goods are valueless until sold," chants the sales staff, "without us the wheels of industry would cease to turn." "The wheels would turn much faster," growls the production department, "if we didn't have so many lame-brains drawing fat salaries as salesmen." Under the cold glance of both groups, the clerical force heatedly inquires: "How long do you think this business would last if we didn't keep the cost records, send out bills and collect the money for pay checks?" Some executives and engineers sometimes forget that their plans cannot be carried out without the cooperation of other groups.

Possibly the greatest single cause of misunderstanding and friction has been fuzzy thinking on social responsibilities. Many of the responsibilities which rested on the individual or the state in our fathers' and grandfathers' days have been shifted to the shoulders of industry. New ones constantly are added or proposed—often before industry has had time to adjust itself to those which have gone before. Some of these responsibilities affect employee relations; others involve customer relations. The worker, for example, no longer is completely defenseless against the occupational hazards of his employment. "Let the buyer beware" no longer is considered smart merchandising. Many of the changes now embodied in the laws were anticipated by industry itself. Opposition —valid or otherwise—to social legislation, however, has been used to damn business in the public eye.

FORTUNATELY, the barriers to good will and common understanding can be broken down. The process is a simple one. It consists chiefly in maintaining good policies in human relationships and in keeping all interested people—employees, stockholders and their neighbors, customers and the general public—informed. It means telling them in plain terms what revenue is received and where it comes from, what revenue is paid out and who gets it, how an industry serves the individual, the community and other industries. Finally, it includes the acceptance of the social responsibilities which the advance of civilization imposes upon business.

Add all these things and you have public relations.

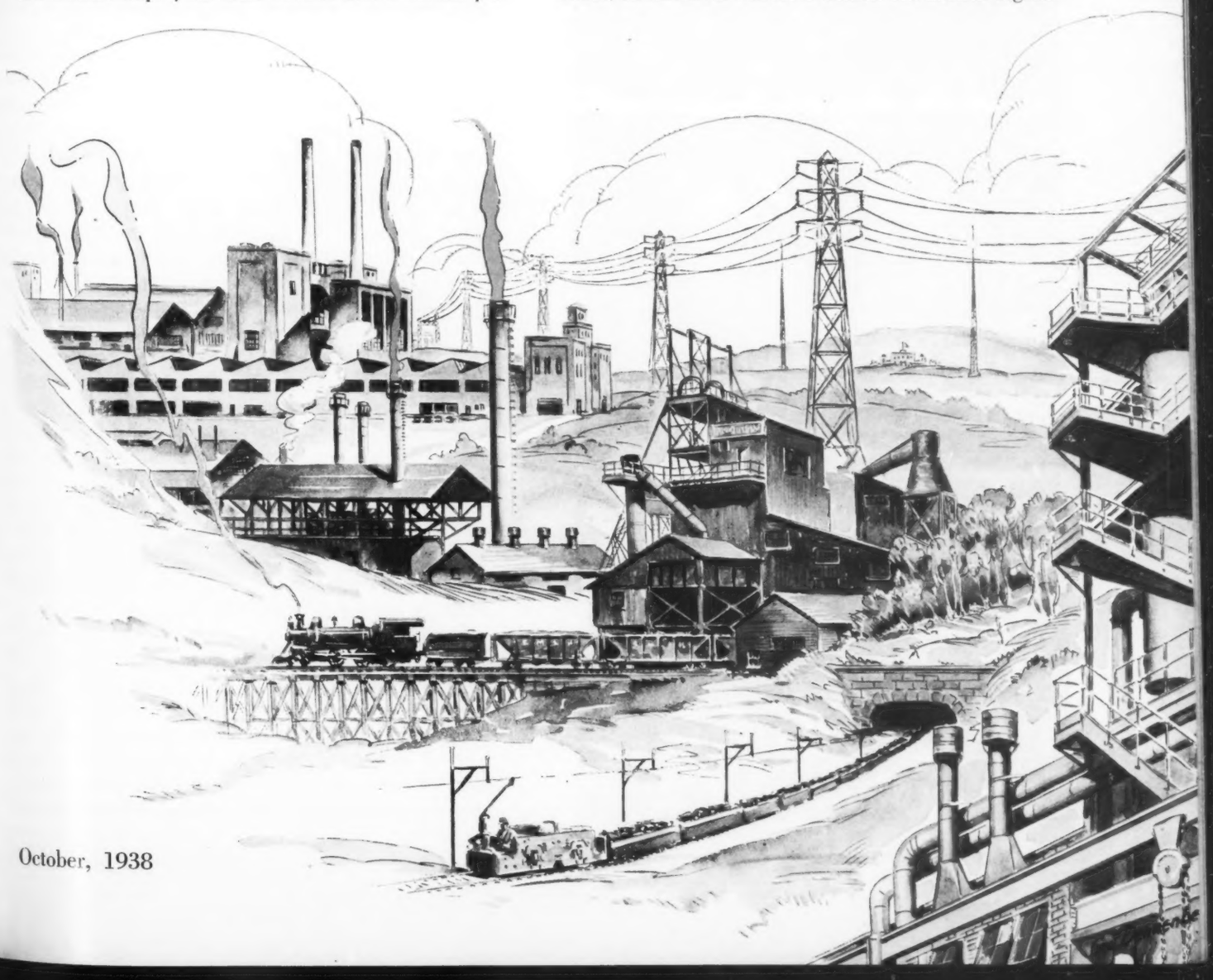
Most employers are willing to accept their social responsibilities, but they are inexpert in making that acceptance articulate. Too many employers have failed to make clear their policies, their practices and their purposes as they relate to fair dealing with employees, investors and the general public. Their intentions have been good, but they have cloaked them with a veil of secrecy and made a mystery out of simplicity. As a result the uninformed have been given a royal opportunity to exercise their imagination. And they have done it!

PUBLIC RELATIONS is a comparatively new activity for most business enterprises and involves a technique which too many have not yet learned. Obviously, the first place for each company to start is within its own organization. This is the "inside job" that builds a company's good name among its own family and lays the firm foundation for building public confidence and favor. As one exponent of the art phrases it: "Industry's public relations cannot be one thing and its private actions and policies something else. The two must be in complete accord."

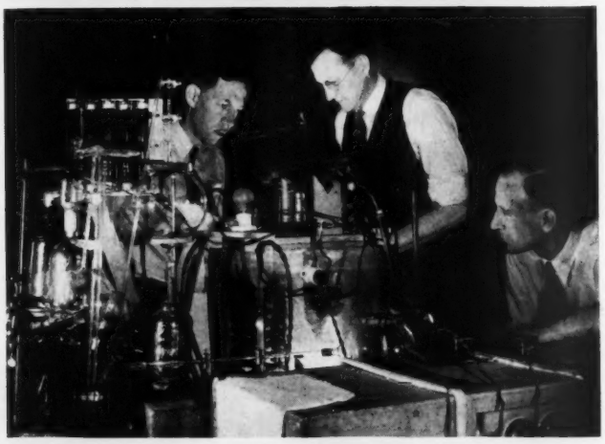
The inside job should present no real difficulties to fair-minded employers. Most workers have a normal predisposition to view in a favorable light the organization in which they earn their livelihood. Most companies endeavor to conduct their operations so as to justify that favorable attitude. But too few of them are adept at dramatizing the facts that furnish a substantial basis for maintaining employee good will. So, where misunderstanding and suspicion born of ignorance exist, time may be required to break down the barriers that have grown up.

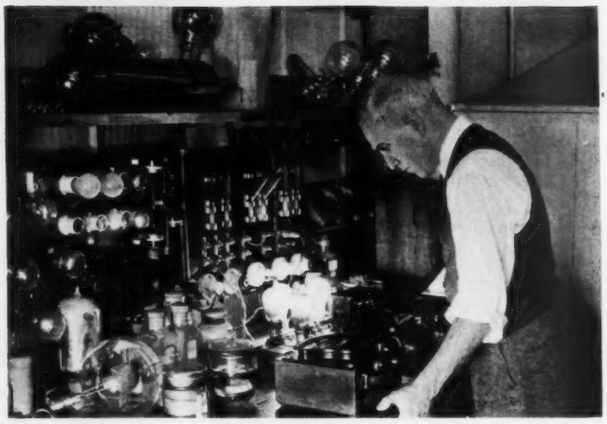
The task of telling this inside job to the outside world, however, will not be easy, for two reasons. First, it has been so long neglected that the backlog of misunderstanding is large. Second, public relations involves attitudes as well as actions, a viewpoint as well as an organization. Public relations is not a commodity that can be purchased like a car of coal or a bolt of silk; neither can it be sold by "canned" material. Each program to establish sound public relations must be individualized and indisputably stamped with the personality of the company promoting it. *And the deed must always back the word!*

But the task is worth the effort. For, with the inside job right, a properly conceived and intelligently executed public relations program offers business the means of counteracting unjust public suspicion, unfair political attack, unwarranted outside dictation. The need is urgent.



Why Industry Must Tell th





GREAT IS the inspiring drama of American industry—armies of workers, mills belching fire and smoke, the mysterious quiet of chemical plants, roaring furnaces and pounding hammers, life-like intricate production machinery, and humming activity along assembly lines. Vast industries pouring forth countless wonders—the material embodiments of new theories, new scientific principles and new discoveries by men of science through the mediums of philosophy, mathematics and experiments. For all progress comes only from the brains of men.

America's great leadership in research and learning is generally recognized. It has placed her in the front rank of industrial progress and has given to her people the highest standard of living the world has ever known. But why does the United States of America hold the place of leadership in science and research? Modern science began in the countries of Europe and England. And those countries had the greatest universities, the finest educational systems, and the governments encouraged and even subsidized learning and research. How was this leadership lost to the United States?

Even before the World War industrial America began to awake to the realization that progress can come only through applied brains—scientific and technological research. At the beginning of the 20th century industrial research had already been well established in the United States. Then came the war and through necessity, perhaps, industrial research forged ahead in a big way. Company after company built or expanded laboratories. The laboratories had to be staffed with trained men of the right type, and such men were scarce. In typical American fashion industry looked the problem squarely in the face and saw the glaringly apparent solution.

Only the universities could supply the men needed for research, therefore, the solution was to support the universities and to encourage them to undertake research. Industrial fellowships were established, experimental laboratories were furnished with apparatus, funds were donated for research projects. America started its quick-time march to leadership. The cooperative effort of American industries to achieve research leadership did not stop

ll the Story of Research

with this united support of industry to learning. Scientific and technical societies were encouraged and received funds from industries in order that general problems might be solved, standards established and information and data of scientific nature correlated. Thus united, industrial effort was brought to bear on many problems. Results have been amazing.

But the spirit of team work carried industry still further in its cooperative efforts. Different industries undertook joint research projects, sometimes even competitors joined in the solution of a specific problem or the development of a much desired material.

Time has proved the tremendous power of the American method of organized industrial research. Industry prospered and as it prospered it put into research more and more time and money. New developments came forth at an amazing rate. Everybody benefited and living standards went up and up. Then in 1929 came economic chaos. Gambling, greed and dishonesty had done their work. Some group had to be blamed, and it is perhaps only human nature that the greatest onus was heaped on "technological developments" and "big corporations." The benefits that had accrued were forgotten and the mistakes made were magnified.

Big corporations have been criticized and accused of exploiting the public through the power gained by the accomplishments of research. There are those who have charged that big corporations suppress patents and keep secret the scientific advances they have made, thus withholding from the public the benefits of the progress of science. Big corporations are being accused in high places of charging exhorbitant prices for patented products. Industry is pictured as throttling progress and the cry has been raised to enact legislation that will make impossible the abuses charged.

The scientific approach to the solution of any problem is to first determine the facts and factors, their magnitudes and their effects. The second step is to analyze the problem to determine what the results might be if one or the other of the factors are changed or eliminated.

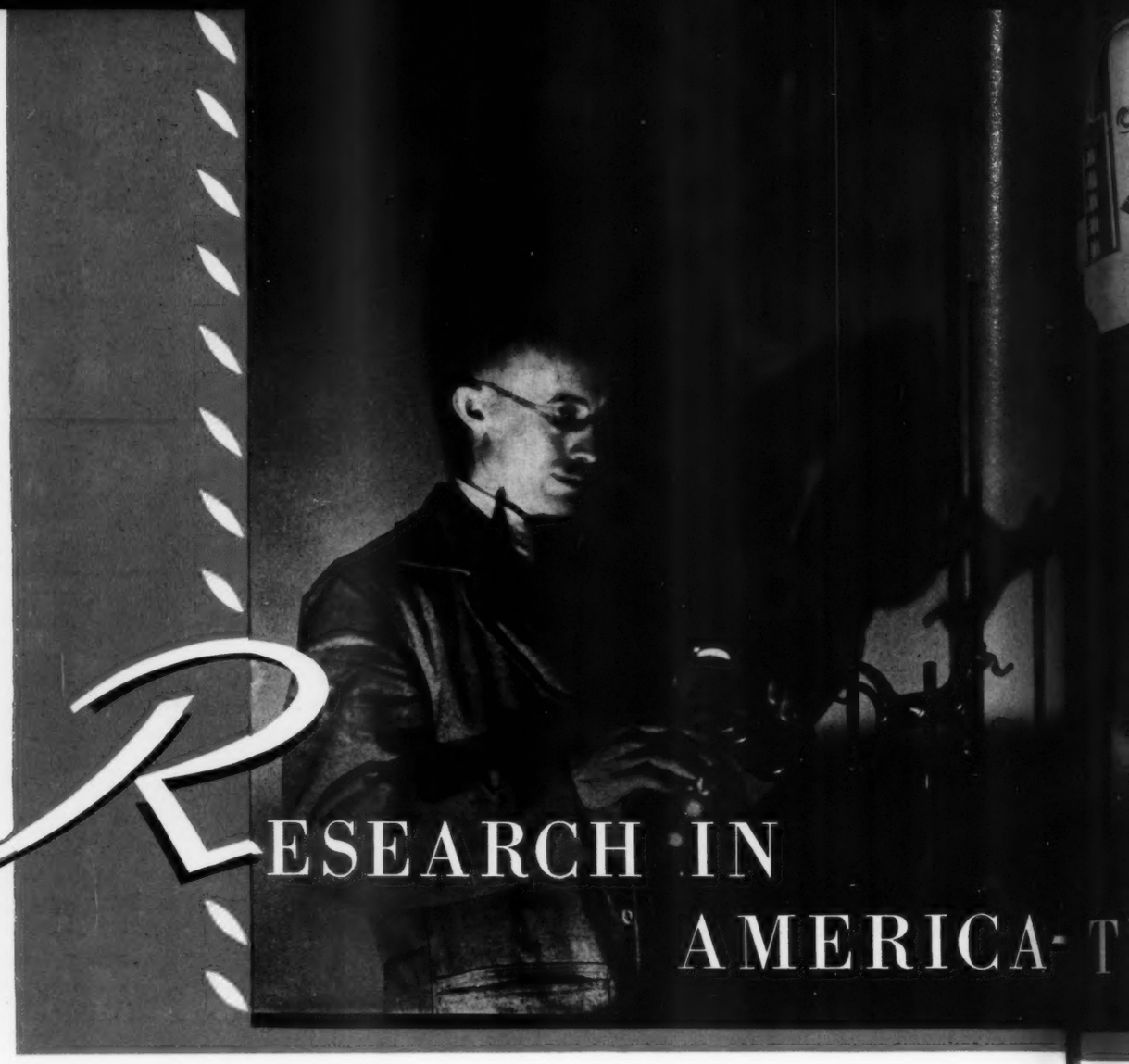
With reference to the problems relating to the future of American industrial research, the following pages aim to give an overall picture of the manner in which American industry operates its research activities, how accomplishments were achieved and what these accomplishments have contributed to the American standards of living. By presenting the facts of research, the article aims to contribute information on which to judge the effects of possible changes in relations between industry, society and government.

Any situations or conditions that would hamper or stop the triumphal march of industrial research would be a national calamity. Dr. L. A. Hawkins, executive engineer of the General Electric Company Research Laboratories, summarized the whole situation in this sentence, "In a world gone mad, let us not neglect our greatest asset and our greatest safeguard for the future—the potential achievements of brain power applied to scientific research in the congenial atmosphere of free inquiry guaranteed by the fundamental principles of democracy."

To estimate "the potential achievements of brain power applied to scientific research," one must scan the record of past performances and give a measure of their value to society. But such a record would be impossible to give in full. Admittedly, words cannot adequately describe the great achievements of research or do justice to men to whom the credit is due. Often many men, groups of men in different companies and even in some instances, a number of industries have all contributed to achieve the final result. And so great in numbers have been the discoveries of research that only a few can be mentioned in even a relatively lengthy article on the subject.

In view of this, the following article is confined to the research activities of several companies, some large and some medium sized. The aim was to include different fields of research so that a broad picture could be presented as an introduction to the succeeding articles.

From this all too meager presentation it is hoped that the readers will gain a clearer understanding of industry-sponsored research and a better appreciation of the work of the men to whom the world owes all of its material progress. May the conditions that made possible their prolific creations continue. Upon their achievements depends the world of tomorrow.



RESEARCH IN AMERICA

TOTAL FIGURES on research in the United States are impossible to establish. Research might be almost academic in one company while in another it is merely design development work. Some companies consider engineering development and even routine testing as a part of their research work. Also, in any given company there is always considerable overlap and an undefinable boundary between research and experimental work, in some companies the same equipment being used for both research and routine testing. Such conditions make it impossible to arrive at even approximate figures on the amount of capital invested in research buildings and equipment, the number of men employed and the total annual expenditures. For these reasons it was decided to limit the figures presented in this article to cover only a few of the largest companies. Even then it has been found necessary to estimate some of the figures. It can safely be said that the errors involved are less than 10 per cent, which degree of accuracy is sufficient to serve the purpose, namely, to give an idea of the extent to which American industry conducts and sponsors scientific research.

The figures given here on research apply entirely to research of a scientific nature and do not include engineering development work, routine testing or engineering work of a similar character. With reference to the figures presented, between 15 and 20 per cent of the time and money spent is on fundamental scientific research conducted for no immediate commercial objective but primarily for the purpose of adding to the fund of scientific knowledge. Between 80 and 85 per cent of the research activities of these major companies is devoted to finding some new material, new process or some commercially useful facts for which a need is felt.

Because complete figures could not be procured, the two greatest research organizations in this country, Bell Telephone Laboratories, and E. I. duPont de Nemours, Inc., are omitted from the accompanying tabulation. According to the figures reported to the Federal Communications Commission, the American Telephone & Telegraph Company spend approximately $19,000,000 per year on research and engineering. What proportion of this expenditure is for scientific or applied research and how much goes for engineering development work, cannot be estimated. E. I. duPont de Nemours, Inc., report an average of $5,000,000 per year for scientific research, and employ approximately 1,200 men in their research department, of whom about 300 are scientists and the remainder technicians, clerks and mechanics.

Industry's contributions to university research projects and to various scientific and technical societies are extremely difficult or impossible to estimate fully. According to figures received from universities the total contributions in the form of industrial research fellowships runs well beyond the million dollar mark annually. As to contributions to various scientific and technical societies, these are not only in the form of cash but, of far greater value, also in the form of

A-THE KEY TO BETTER LIVING

services rendered by the employees of industry in serving on research committees of societies and associations. It has been estimated that in addition to $50,000 annually contributed by industries in support of the more than 150 research and standardization projects conducted by the American Society for Testing Materials, industries spend a total of about $350,000 annually for tests conducted in their laboratories by the 1,750 men from industry for the A.S.T.M. research committees on which they serve. Similar figures apply to all other national scientific associations and societies.

In contemplating the value of the support given by industry to scientific societies and technical associations, it must be borne in mind that it is mainly through the medium of such societies that engineers and scientists exchange views and information and that data are correlated and distributed to the scientific world.

But the expenditures for research are not a measure of its value to humanity. This can only be judged by the accom-

THESE SIX COMPANIES—

Aluminum Company of America

Eastman Kodak Company — *General Motors Corporation*

General Electric Company — *International Nickel Company*

Westinghouse Electric & Mfg. Company

•

Have invested a total of more than $8,250,000 in research buildings and equipment

Employ a total of more than 750 research scientists assisted by 1,200 clerical workers and mechanics

And in 1937 spent a total of more than $6,500,000 on scientific research

Seeking more knowledge about flourescence to create better lamps. Bombarding flourescent minerals with cathode ray at Westinghouse Research Laboratories

General Electric's famous research triumverate — G.E. research men say, "Dr. W. R. Whitney, director of research, plays hunches with uncanny precision, while Dr. W. D. Coolidge is 'the great experimenter' who always seems to hit it right, while Dr. Irving Langmuir, Nobel Prize winner, is 'the great thinker' who is a 'shark' at mathematics

plishment of research, and then only in an abstract manner. Admittedly, it is relatively easy, for example, to figure the millions of dollars saved by the higher efficiency of modern electric lamps and the lower cost of electric power. But how can the values of lives saved, eyesight conserved, the greater comfort of life and other benefits of better lighting be translated into dollars and cents? Considering one of the latest developments in lighting, the Sterilamp which has the power of killing bacteria germs and microbes, how can one place a dollar value on its contribution to better living? There is also the development of X-ray equipment, artificial fever machines and the numerous electrical devices for medicine and surgery.

One of the most striking stories in the annals of American research is that of the development of the modern electric lamp. Invented by Thomas Edison in 1879, the first commercial installation of his carbon filament lamps was a few years later in the Pearl St. district of New York City.

The first large spectacular installation of electric lighting was at the Chicago World's Fair in 1893, where 250,000 lamps were installed by George Westinghouse.

The early lamps were fragile, had a short life and gave three lumens of light per watt of energy consumed. It was not until 1905 that any appreciable

improvement in electric lamps was made. At that time Dr. W. R. Whitney, director of the newly organized General Electric Company Research Laboratories, was experimenting with the newly invented electric furnaces.

Many scientists were studying the possible improvement of the electric lamps—Dr. Whitney among them. He thought that possibly he might be able to do something by experimenting with carbon filaments, using the new high temperatures made available by the electric furnaces. After much study and experimenting he hit upon the idea of treating the carbonized cellulose filament with gasoline vapor and then heating the filament to a high temperature. He found that this produced a graphite like structure by virtue of which the filament was given some of the properties of a metal and thereby reduced the rate of evaporation of the carbon. The Gem lamps made with this "metallized" carbon filament had about 25 per cent more efficiency than the previous carbon filament lamps.

Dr. Fonda of G.E. measuring the illumination given off by flourescent materials exposed to ultra-violet light

Dr. Young in the G.E. Lab at Schenectady investigating the illumination given off by a sodium vapor lamp

It was well recognized at that time that the metal tungsten, because of its high melting point of 6,100 deg. F. would be an ideal material for lamp filaments. Also, it had an extraordinarily low rate of evaporation. But tungsten was extremely brittle and could not be drawn into fine filaments for use in lamp bulbs. German inventors had produced a cast filament which was extremely fragile and therefore impractical. An improvement on this cast filament was made by mixing powdered tungsten with a paste and squirting it through small holes in a die. The paste was then driven off by heating the filament by passing an electric current through it in an atmosphere of hydrogen or nitrogen gas. This filament was also extremely brittle. but was used for lamp filaments for six years.

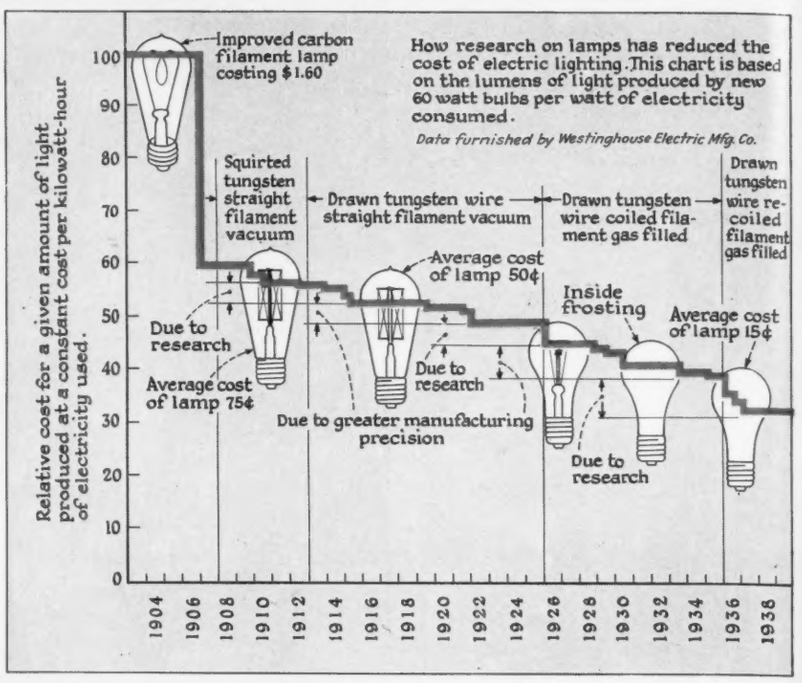
There were several difficulties with the first tungsten squirted filaments. They were very brittle and were made in sections and ends pasted together to form the complete filament. They did not burn well on alternating current. W. G. Housekeeper and H. D. Madden working in the Westinghouse Research Laboratories, finally found in 1909 how

to press and squirt or extrude a continuous thread of powdered-tungsten paste which upon heating in a protected atmosphere became a solid tungsten filamosphere became a solid filament.

Discovery of Ductile Tungsten

In 1905 Dr. W. D. Coolidge joined the General Electric Research staff and the problem of producing ductile tungsten interested him. In 1906 he discovered the amalgam process by which he made ductile thick squirted filaments from which wire was drawn for high wattage and series lamps.

For five more years he and his staff studied and experimented with different possibilities and finally, in 1911 got the answer to his problem. He pressed powdered tungsten into a cake, heated it in a furnace to almost the sintering temperature, took it out of the furnace and passed an electric current through the cake of tungsten to heat it to the sintering temperature. The current was shut off and the tungsten was hammered while hot. This last operation was repeated several times, heating to successively lower temperatures and finally there was produced—ductile tungsten. The resulting lamp, which was put on the market in 1913, had twice the efficiency of the best carbon filament bulbs, but these vacuum bulbs with tungsten filaments also blackened.



The amazing record of results of researches in light. If the illumination of 1937 had been attempted with the lamps of 1900, it would have cost $2,000,000,000 more for electricity alone at present power rates

Sodium vapor lamps required much research before they could be made commercially available

Numerous other developments followed in rapid succession. Pacz of G.E. in 1915 solved the problem of the filaments sagging out of shape. R. D. Hall. Harry H. Smith and J. H. Ramage made improvements on Pacz's solution. The research activities of Marvin Pipkin of the General Electric Company in 1925 brought into being the inside-frosted lamps. In 1926 W. B. Gero of Westinghouse discovered how to alloy tungsten so as to make possible control of size and shape of grain and thereby eliminate the twisting of the filaments when at the operating temperature.

In 1909 Dr. Irving Langmuir changed his job from that of instructor in chemistry at Stevens Institute of Technology to that of research worker in the General Electric Laboratories. When he reported for his new job, he asked Dr. Whitney, his boss and director of the laboratory, for a research job to start on. Dr. Whitney said "I suggest you take a look around the laboratory and see if there isn't some problem that might catch your fancy."

The Gas-filled Lamp

Langmuir took a look around and noticed the blackening of the tungsten filament bulbs. Here was a problem that many minds were working on and the problem caught Langmuir's fancy. He immediately started working on it.

Quite naturally, Dr. Langmuir suspected that the blackening of the bulb was caused by the oxidation of the tungsten filament by the residual oxygen in the vacuum bulb. But the bulbs were evacuated as much as possible with the equipment then available. So Langmuir decided that his first job would be to develop a new bulb-exhausting technique to enable him to produce higher vacuum. Finally Langmuir succeeded in making lamps with vacuums much higher than previously obtainable. But it only proved to him that he was on the wrong track, the higher vacuum did not

Stretches of hazardous highway illuminated by sodium vapor lamps such as this Westinghouse installation, have reduced night fatalities as much as 82 per cent

seem to affect the blackening of the bulbs one way or another.

Then Langmuir reasoned, "If less air has no effect, what will be the effect of more air, or putting in more inert gases". And thus he discovered that filling the bulb with an inert gas at atmospheric pressures prevented blackening. From this he concluded that the blackening of the bulb was caused by evaporation of the tungsten and that when the inert gas was put into the bulb, some of the molecules of the inert gas got in the way of the tungsten molecules being evaporated, thus causing them to rebound back on the filament. As a result of these researches, the electric lamp bulbs were filled with inert gas—argon, with 10 to 15 per cent nitrogen to suppress the arc formed when the bulb burned out. These lamps were inherently no more efficient, and in some sizes less efficient, than the vacuum-bulb tungsten filament lamps, but their life was longer.

It was an investigation of electric toasters that led to the next great lamp discovery. It has been supposed that the total heat loss from an electric resistance ribbon was proportional to the exposed area of the ribbon. But an associate of Langmuir, investigating the laws of operation of electric toasters discovered that the proportionality of superficial area to heat loss did not hold except to a certain degree. This being so, reasoned Langmuir, more light without appreciably greater heat loss could be obtained by a filament that exposed a greater area. Coiling the filament would have this effect. In 1926 the drawn tungsten wire coiled filament gas-filled electric lamp was put on the market.

During the past decade further developments in electric lighting units have been amazing. The coiled-coil filament, most effective in bulbs from 25 to 60 watt capacity, further increased lamp efficiencies to about 15 lumens per watt, more than five times as efficient as the Edison bulbs of 1879. The accompanying chart portrays the step by step developments of the 60 watt electric lamp from 1903 to date. And further improvements are in the offing.

The Sodium-Vapor Lamp

Perfected within the last several years are the sodium-vapor lamps which are especially suited for highway lighting. To perfect these lamps required finding out how to prevent discoloration on the inside of the bulb caused by sodium atoms diffusing into the glass. Finally, in 1936, after years of research, a special glaze that would not permit the diffusion of sodium atoms into it was developed. This glaze was applied to the inside of the bulb, and the sodium vapor lamp was ready for use.

Although these bulbs have not yet

The "Peanut" lamp undergoing tests at the Westinghouse laboratories. The light intensity is twelve times that of a filament bulb, thereby making possible correspondingly more powerful searchlights and airplane beacons

come into general use for highway lighting, they have been installed on numerous stretches of highway where driving conditions are hazardous.

These lamps give as much as 50 lumens as compared to 12 to 15 lumens per watt for Mazda lamps of comparable capacity. But their greatest value lies in the color of the light produced. It is the color best suited for seeing; ideal for highway lighting because it makes visible in great detail objects even at a great distance. Numerous reports from State Highway Commissions all tell the same story—hazardous stretches of highway on which these new sodium vapor lamps have been installed have shown a great decrease in fatal accidents.

Mercury Vapor Lamps

The most recent lighting unit developments have been in the mercury vapor lamps. Much of the energy given off by the old Cooper-Hewitt lamp is in the form of ultra-violet waves—invisible light. If this short-wave energy could be transformed to a longer wave length it would add that much more "visible" light to the output of the lamp. The research workers of the General Electric and Westinghouse Companies, and others in foreign countries, found out how to do it. The solution was to coat the inside of the mercury tubular lamps with compounds that fluoresce under the action of ultra-violet rays, thus converting the short wave into longer wave lengths of "visible" light. The resulting flourescent Mazda lamp can be coated to give forth a light approaching sunlight more closely than any other lamp. It produces 25 lumens per watt as compared to about 15 lumens per watt delivered by the modern 60-watt Mazda bulb. Also, the tubes can be coated so that the lamp gives forth light of any desired color. In such applications their efficiency is many times that of the ordinary colored-glass lamp bulb in which much of the light is absorbed by the colored glass. Man is making great progress in his struggle to approach with artificial lamps the efficiency of the firefly.

High-Intensity Lamps

Still further progress in electric lamps is in view. There has long been a great desire for light sources of piercing intensity to be used for searchlights and projectors. Recently there has been announced by the Phillips Company of Holland and later by the General Electric Company and Westinghouse the perfection of the "Peanut" lamp, a water-cooled mercury vapor lamp. It is a tiny quartz tube about the size of a peanut. The bore is 1½ mm., the outside diameter 4½ mm., length about 1 in. A little pool of mercury at the bottom of the vertically held tube, which is sealed at each end, is heated to its vaporization temperature by a hot cathode. Once the mercury has vaporized, the current

flows through the bore of the tube. When fully warmed, this mercury vapor lamp reaches a temperature of more than 11,000 deg. F. in the core of the capillary bore and develops a pressure of about 25 atmospheres. It delivers up to 4,000 lumens at an intensity about 12 times the intensity of a filament projection lamp. The value of the increased safety in air and water navigation resulting from the superior searchlights obtained is beyond calculation.

Still greater brightnesses are obtained when these lamps are water cooled. A 1,000 watt water cooled lamp has an internal diameter about the size of the lead of a lead pencil and a length of only about one inch and delivers about 35,000 lumens of light.

Dr. Marden with others of Westinghouse has for several years been studying other metal vapor discharges such as zinc, cadmium and others, the most striking of all being tellurium vapor which has a continuous spectrum in contrast to other discharges which have line spectra.

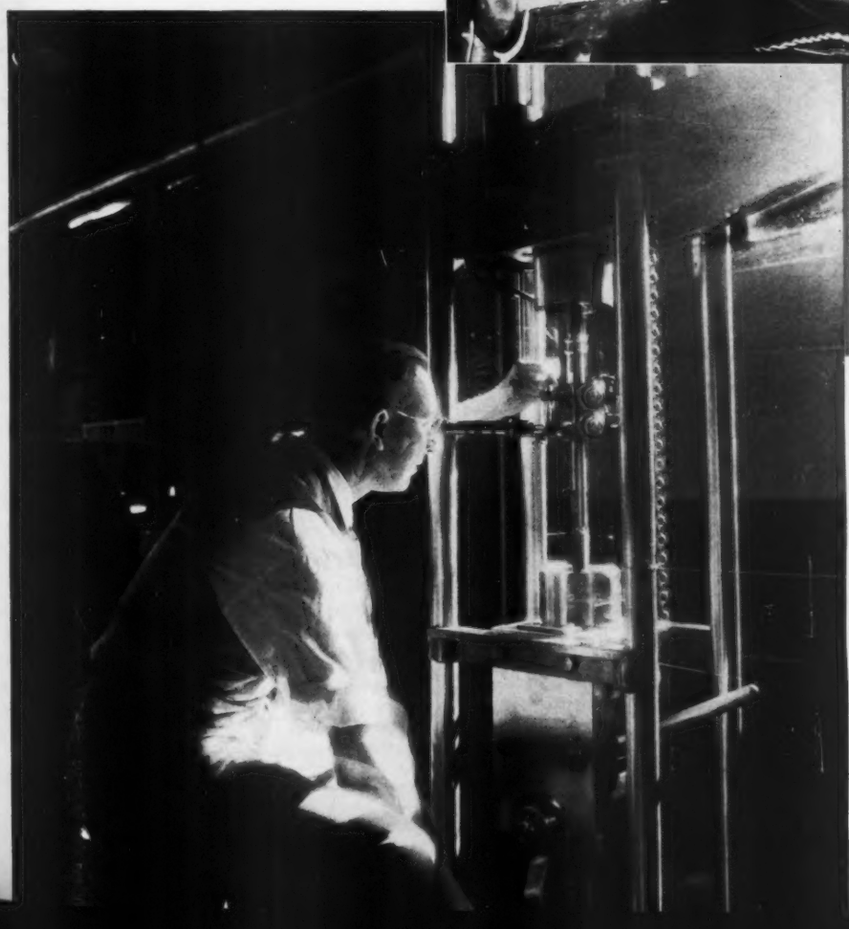
Also much fundamental work on arcs and discharges is being done at Schennectady by such able experimenters as Found and Suits. Meanwhile practical lamp engineering studies by Inman of G.E. at Cleveland, by Nisely of Westinghouse at Hoboken, N. J., and Gustins of Westinghouse at Bloomfield are resulting in lamp designs of ever greater efficiencies and usefulness.

Bacteria Killing Light

Dr. Robert F. James of the Detroit Edison Company was very much annoyed with the mustiness in the refrigerator in his apartment. Frequently, bacteria developed on the food and spoiled it. His wife complained and that annoyed him more so. She couldn't understand why scientists who could do so many wonderful things could not do such a simple thing as eliminating the mustiness from her refrigerator. So Dr. James decided that he would have to do something about it. Naturally his first thought was to use an electric lamp. Sunlight killed bacteria—why not electric light? But the heat of the lamp would defeat the purpose of a refrigerator. So he built a low-temperature mercury vapor lamp which, because of its high efficiency, remained relatively cool.

"My superior in the laboratory decided he would see just how good my lamp was," Dr. James related, "so he brought a moldy duck to the office. This duck had been shot on the east coast and was well spoiled when it arrived, covered with mold. I put it under the lamp, and twenty-four hours later was much surprised to find the mold dried up so that it could be blown off. Well, we had that duck for dinner, and it was good." But Dr. James had no way of telling exactly which wave length of light had done the bacteria killing.

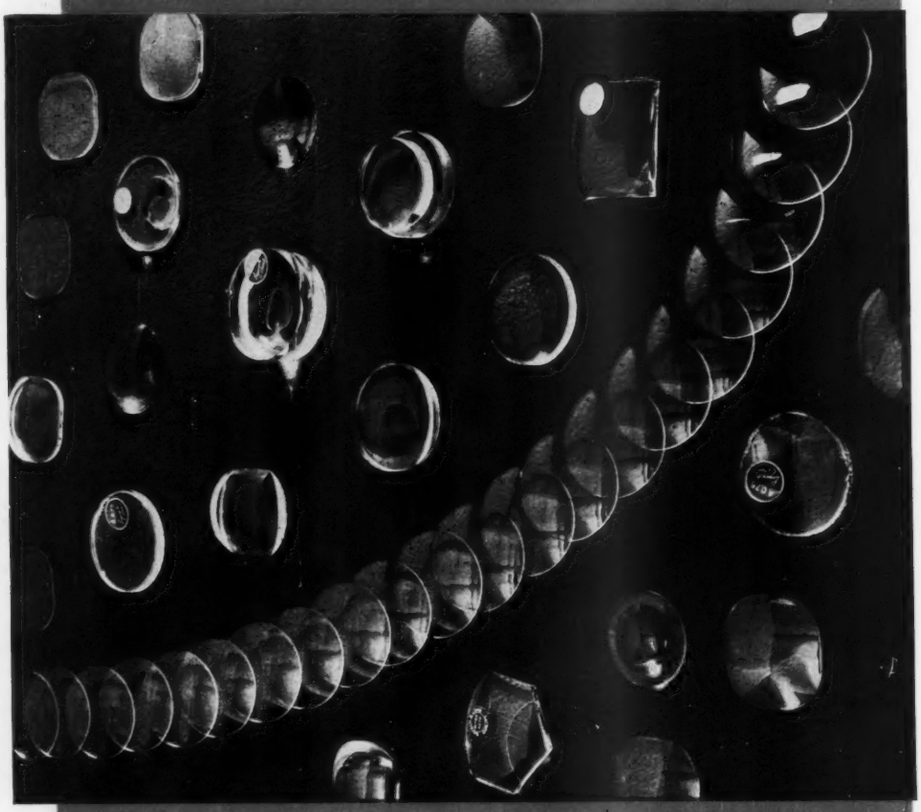
During this same time and entirely unaware of the activities of Dr. James, Dr. Harvey C. Rentschler, director of research at the Westinghouse Laboratories in Bloomfield, N. J., decided to find out exactly which band of the solar spectrum had the power to kill bacteria. Of course he knew that these bands lay in the ultra-violet portion of the spectrum and thus he was faced with the



Westinghouse's famous Dr. Slepian in his private experimental laboratory. His best-known accomplishment is the Deion circuit breaker, his greatest accomplishments are his contributions to scientific knowledge

Materials — the essential ingredients of every successful design. Investigating them to establish their properties is the biggest single job of research

Dr. H. C. Rentschler, director of research at the Westinghouse Lamp Division, with Dr. Robert F. James pushing the slide rule, making one of the intricate calculations in the course of their development of the Sterilamp



Opthalmic lenses, Bausch & Lomb makes about 20,000,000 annually, in which the marginal images are as sharp as through the center — thanks to the curves computed by Dr. W. B. Rayton

problem of devising some means to measure the invisible ultra-violet waves. There was no known instrument or technique and he had to find out how to do it. He did. He produced an "ultra-violet meter" which separated and measured the wave lengths of ultra-violet light.

Happily in about 1933 the two doctors, Rentschler and James, met at a meeting of a scientific society and, perhaps over a few cocktails, started "swapping stories". Dr. James told his duck story. Rentschler said he had a better one than that and told his story of the ultra-violet meter. They quickly realized that the two stories put together would make a better one still. And thus it came about that Dr. James joined the research staff at the Bloomfield Laboratory of Westinghouse.

For five years Rentschler and James, with a staff of assistants, studied, calculated and searched to find the exact wave length which had the power of killing bacteria. They experimented on the paramecia germs. A total of more than 50,000 man-hours were spent in tedious and painstaking experiments and research. At last they found the answer to their question. The wave length of 2,537 Angstrom units gave the rays dealing death to bacteria and microbes, but were harmless to human beings.

This discovery was only the beginning. An entirely new lamp with a new type of glass capable of transmitting the death-dealing rays had to be developed. A sturdy inexpensive commercial type lamp had to be designed. And then the effectiveness of the lamp in its practical applications had to be proved. In the spring of 1938 the Sterilamp, as it is called, was ready for its service tests.

Operating rooms in several hospitals have been equipped with Sterilamps. Accurate records are being kept to determine whether or not the operating rooms that are equipped with Sterilamps show fewer cases of infected operations. Will the germs blister and burst in the light from the Sterilamps as did the paramecia germs experimented on in the laboratory? Time will tell how great a boon the Sterilamp may be to humanity. But the Sterilamp has already proved its efficacy in destroying mold in refrigerators and in storage places and in sterilizing dishes in restaurants.

Optical Glass and Lenses

Prior to 1917 all optical glass was made in Europe and when the United States entered the World War America's supply quicky became nearly exhausted. Fortunately, in 1912 William Bausch, son of John Jacob Bausch, co-founder of the Bausch & Lomb Optical Company, had already begun experiments to find out how to make high-grade optical glass.

It was not only a problem of discover-

Born in the Twentieth Century of Research and Invention

★

AVIATION

★

11,750 Employed in Air Transportation

36,000 Employed in manufacturing aircraft

Plus thousands more engaged in furnishing manufacturing materials and operating supplies.

549,000,000 passenger-miles were flown and 11,000 tons of mail were carried in 1937 — with a safety record of more than 12,000,000 miles of flight per fatal accident.

MOVING PICTURES

★

28,500 Employed in producing movies

12,500 Employed in distributing movies

241,000 Employed in exhibiting movies

Plus thousands more engaged in making cameras, projection machines, film, and equipment.

Besides the millions who enjoy the shows, moving pictures are playing an important part in education and scientific investigations.

RADIO

★

50,000 Employed in manufacturing receiving sets

50,000 Employed in radio broadcasting

Plus thousands engaged in selling and servicing radios.

28,000,000 American homes—82 per cent of the total — have one or more radios for news and entertainment, while in fire, flood, marine disasters, radio has contributed services that cannot be evaluated.

429,750 Employed directly in Aviation, Movies, and Radio, plus tens of thousands who indirectly get employment from these industries.

ing the mixture of raw material that would give the desired properties to the optical glass. Temperature control in the melting was soon realized to be an important factor. Then it was discovered that the chemical composition and physical properties of the ceramic materials out of which the melting pots were made greatly affected the quality of glass produced. Also, annealing processes had to be developed in order to produce optical glass free from internal strains. By 1915 Edward Bausch was producing optical glass of a quality that compared favorably with the best that had been imported. And finally, the necessary machinery for grinding lenses to the high degree of accuracy required had to be designed. Thus in the United States were developed lenses of the highest quality for range finders, periscopes, binoculars, aerial cameras, telescopic gunsights, searchlight reflectors and similar instruments.

When the United States entered the World War in 1917 the government

A man of many interests, Dr. Wilbur B. Rayton, director of the Scientific Bureau of the Bausch & Lomb Optical Company. Mathematician and physicist, he developed the fastest lens ever produced for astronomical spectrography

In several hospitals, operating rooms are equipped with Sterilamps to reduce infections contracted in operations. Preliminary reports are highly encouraging

Dr. Wilbur B. Rayton of Bausch & Lomb holding a discussion meeting with his staff. Standing, left to right, are James R. Benford, George W. Gallasch, John R. Miles and Arthur A. Levine. Seated at Dr. Rayton's left are Henry F. Kurtz, Gustave Fassin and Leon V. Foster. At Rayton's right are Frederick W. Jobe, Maxwell Hill and E. M. Brockway

Dr. G. R. Fonda of G.E. demonstrating the difference between a flourescent tubular lamp and the ordinary Mazda tubular lamp which he is holding

turned to Bausch & Lomb Optical Company to provide optical glass from which to make lenses for the many instruments required. Production was doubled within thirty days and then doubled again. Research activities were intensified and the problems in the manufacture of optical glass and lenses were attacked with greatly increased vigor.

When the war was over Bausch & Lomb decided to go after research in a big way. The Bausch & Lomb Scientific Bureau was established with Dr. Wilbur B. Rayton at the head of it and a corps of able assistants, all men who had devoted years to mathematics and physics.

Great as were the contributions of

In the micro-laboratory of Westinghouse, studying microscopic particles of matter, a field of science that is becoming of ever greater importance

Bausch & Lomb to national defense, they have been greatly overshadowed by the subsequent achievements of their Scientific Bureau when results are measured in terms of benefits to humanity. Space does not permit a detailed account of these developments. They are a story in themselves. But a brief summary at least gives some idea of the part played by the Bausch & Lomb Scientific Bureau in its contributions to better living.

Microscopes for Science

In addition to the conventional microscope such as used by the medical profession for making blood and bacteria counts, and used by metallurgists for studying grain or crystal structures, other types have been designed to fill particular needs. The Microtome cuts tissues samples from any part of the human or animal body into slices as thin as 1/25,000 of an inch. Scientists needed an instrument with which these tiny organisms could be handled and dissected. For this purpose, the Fitz Micromanipulator was developed, a microscope that is equipped with tiny mechanical fingers and dissecting knives by means of which the scientist can manipulate and dissect the minute tissues while observing them through the microscope.

Another field of study in medicine was to determine the effect of pressure on micro-organisms. The centrifuge has long been used to separate solids from liquids. This device was also used to develop pressures in liquids containing micro-organisms, but there was no way of determining what was happening to the micro-organism. This led to the development of the new Harvey-Loomis centrifuge microscope with which one can see through a microscope the micro-organisms as though they were standing still, though they are whirling at the rate of 10,000 r.p.m., thus permitting the study of the effects of increasing pressure on the organisms.

Undoubtedly the whole scientific world would never have reached the present high plane were it not for the availability of powerful microscopes. Rare is the piece of research that does not require the use of optical instruments. Refractometers for analyzing colors, the spectrographic apparatus to determine the elements in material being analyzed, polariscopes for locating strains in glass ware, opacimeters for determining the opacity of papers, X-ray sterescopes with which equipment the physician can obtain pictures of internal organs in three dimensions, and photomicrographic apparatus for recording all of the phenomena of microscopic structures.

Recent Developments

Latest in the development of optical instruments is the spectrograph, now coming into general use in the fields of metallurgy, chemistry, physics and biology. Using quartz optical systems which are capable of transmitting the ultra-violet waves, the spectrograph is capable of detecting as little as 1/80,000,000ths of a milligram of an element in a minute sample volatilized on graphite electrodes. No element, no matter how insignificant in quantity, can escape identification and through the use of the spectrograph quick and accurate analyses can be made on minute samples. The value of this development to science, industry and society is beyond estimation.

Another recent development in optical equipment is the use of polarized light in metallographic equipment. The polarized light eliminates surface glare and reflections, thus exposing the true colors of the surface and enabling the identification of different ingredients.

It would be impossible to describe all of the uses for lenses. Suffice to say, medicine, surgery and science would still be in their infancy and photography and motion pictures in their present high state of development would not exist were it not for the amazingly accurate and powerful lenses now produced. Research made it possible to produce them.

Contributions to Education

As their Scientific Bureau grew, and their business along with it, the heads of the Bausch & Lomb Optical Company realized that it would be good to create sources for a supply of brains and technical skill to carry on their work to still higher levels. So they founded the Mechanics Institute of Rochester, an institution designed to give training in all the mechanical arts. Then Bausch & Lomb and the Eastman Kodak Company jointly sponsored the Institute of Applied Optics which is now housed in the Bausch & Lomb Physics Building, donated by Bausch & Lomb to the University of Rochester. These are examples of the generous vision and interest displayed by many American companies and industrialists in improving the facilities for education and the training of men who furnish the brain power that spells progress.

Researches in Materials

In this introductory article only an insignificant portion of the great story of Research in America has been told. Though much has been contributed to better living by the amazing developments in electric lamps and optical lenses, even more amazing have been the accomplishments of researches in materials and electronics.

It has been said that progress can be no faster than the rate of developments in new materials. This has been illustrated in the history of the electric lamp that had to await the discovery of ductile tungsten. It is again illustrated in the history of lenses and microscopes, that had to await high-grade optical glass.

The next article of this series which will appear in the November number, will give an account of some of the accomplishments of research in the field of materials.

BEARING CONSTRUCTION

Its Relation to Performance and Life

ALBERT B. WILLI
Chief Engineer, Federal-Mogul Corporation

Analysis of test results which shows that the life expectancy of engine bearings is largely dependent upon manufacturing methods as well as upon the materials used in construction

IN THE never ending search for new materials and design refinements with which to increase the life and load capacity of bearings the possibilities offered by some of the known materials and designs are often overlooked and neglected. Conventional tin-base babbitts seem to be outstanding examples of this inattention.

Babbitt composition or analysis to secure certain physical properties has always been considered to be of governing importance in babbitt-lined bearings, both in the steel and in the bronze-backed types. Obviously this is important, but in addition the manner in which the babbitt in the lining and the steel or bronze in the back are utilized are of equal importance. The truth of this statement is evident from test observations.

A 100-hr. endurance test run on four groups of connecting rod bearings made by different manufacturers revealed some interesting data. The engine in which the bearings were tested was mounted on a hydraulic dynamometer. All the bearings tested were steel-back, babbitt-lined and of the Precision type. The composition of the babbitt in all bearings was practically identical, as was also the steel analysis. The design elements also were identical in all. The wide variation in the condition of the various groups of bearings after test, which are shown in Figs. 2, 3, 4, and 5, cannot therefore be attributed to differences in material composition nor in design. Throughout the tests extreme care was used in duplicating assembly and operating conditions to make sure that no variable factor was introduced which might affect the life of the bearings. The designations Type A, B, C and D in Fig. 2, 3, 4, and 5, were used to identify the product of each manufacturer.

To explain why one group of bearings can pass the test with an area of failure of only 19.4 per cent and another group is able to withstand only 60 hr. and 14 min. of the projected 100-hr. test requires an investigation of the methods used in the manufacture of the various groups.

A steel-back babbitt-lined bearing can be made by either of two different basic methods of manufacture, namely, from flat babbitted strip steel such as is shown in Fig. 6(A) or as shown in Fig. 7 from steel tubing with the babbitt centrifugally cast (spun in). A number of variations which pertain mainly to the application of the babbitt and the preparation of the steel for babbitting are possible in both processes.

These different methods of manufacture and their variations differ in cost and very evidently establish a corresponding range in life expectancy or mileage within certain limits. In the making of cheap bearings certain operations may be omitted or they may be performed differently, however, in the finished product it is practically impossible to distinguish any differences between a cheap bearing and an expensive one. The cheapest steel-back babbitt-lined bearing can be roughly rated to carry a maximum unit pressure of 800 to 1,000 lb. per sq.in. for a given period of time under certain operating conditions, and the most expensive bearing of the like style can be rated to carry 1,400 to 1,500 lb. per sq.in. for the same length of time under the same operating conditions.

If the work to be performed is within an 800 lb. per sq.in. rating, it is obviously questionable economy to use a more expensive bearing, but conversely, the cost differential sometimes becomes a powerful temptation to apply the 800 lb. per sq.in. product in places where conditions demand a bearing of higher capacity.

The most inexpensive steel-back babbitt-lined bearing is made from flat babbitted strip steel. Such bearings have obtained a high degree of popularity, particularly in passenger car applications. To overcome certain bearing ailments in heavy-duty work attempts have been made to use bearings made from steel tubing with the babbitt centrifugally cast-in and with the back surface ground after babbitting. There is no assurance, however, that such bearings will possess any improvement unless certain points are properly established, which particularly involve the length of the tube to be babbitted and the preparation of the inside of the tube for babbitting, and the place of the back-grinding operation in the sequence of operations.

The length of the tube to be babbitted is a very important consideration in the maintenance of uniform quality of bond and babbitt structure. As shown in Fig. 7 the cooling or solidification of the babbitt should be directed from the center of the tube toward the ends. If the tube

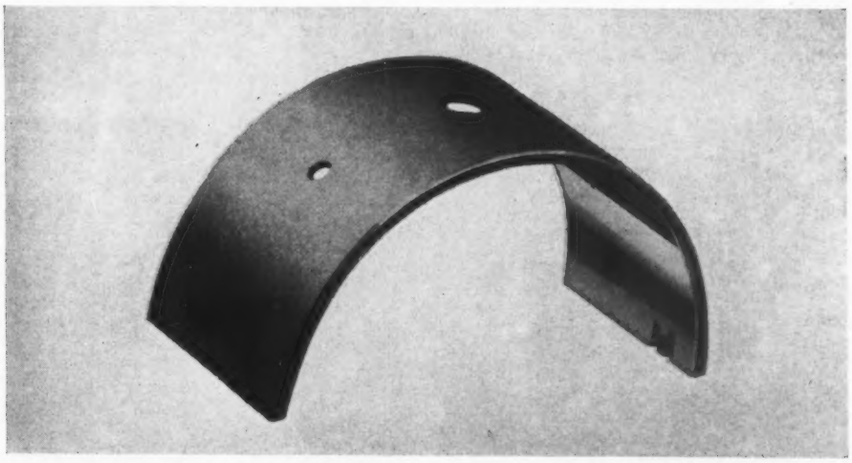


Fig. 1—Steel-back babbitt-lined bearings have a range life expectancy which depends as much upon method of manufacture as upon the materials from which they are made

Comparative Tests on Engine Bearings

FOUR SETS EACH STEEL-BACKED AND BABBITTED

Material Analysis

Steel back.....all S.A.E. No. 1010

BABBITT

	Copper	*Antimony*	*Tin*	*Lead*
Type "A".....	3.50	7.50	88.75	0.25
" "B".....	3.38	7.91	88.62	0.09
" "C".....	2.30	7.41	90.10	0.19
" "D".....	3.68	7.89	88.25	0.18

Conditions of Test

100 hr. at.....3,700 r.p.m.
Lubrication.....S.A.E. 30 Mobiloil
Oil sump temperature.....205 to 210 deg. F.
Max. unit pressure.....1,646 lb. per sq. in.
Mean unit pressure.....1,059 lb. per sq. in.
PV (rubbing factor).....33,150
Zn/P (bearing factor).....20.5

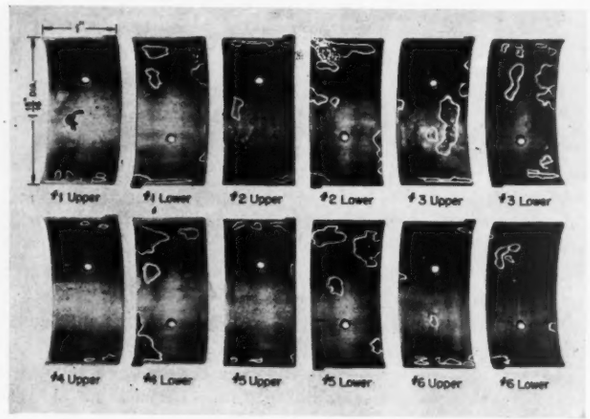


Fig. 2—Type "A" bearings at conclusion of 100-hr. standard endurance run. Total area of failure in all bearings is 19.4 per cent of total developed bearing area

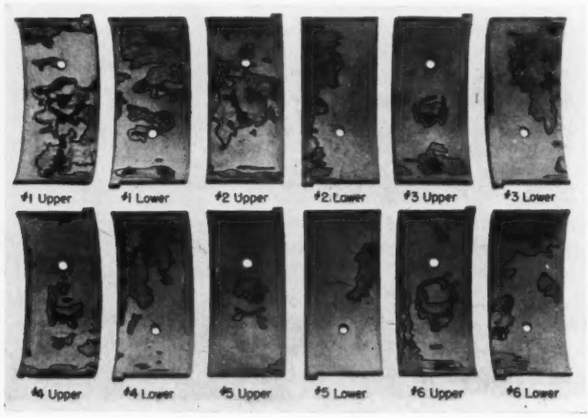


Fig. 3—Type "B" bearings at conclusion of 100-hr. standard endurance run. Total area of failure in all bearings is 27.79 per cent of total developed bearing area

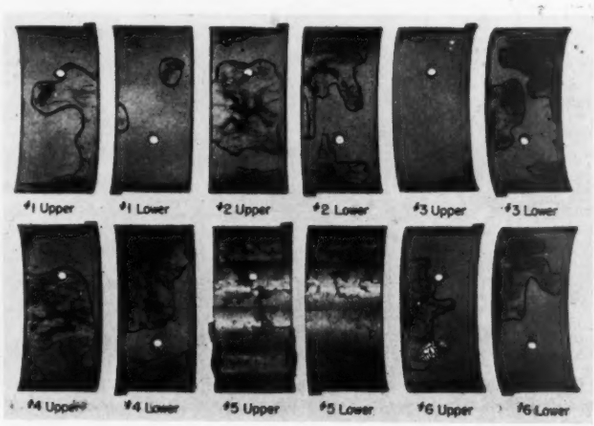


Fig. 4—Type "C" bearings after 90-hr. run. Number 5 bearing failed completely. Total area of failure in all bearings is 55 per cent of total developed bearing area

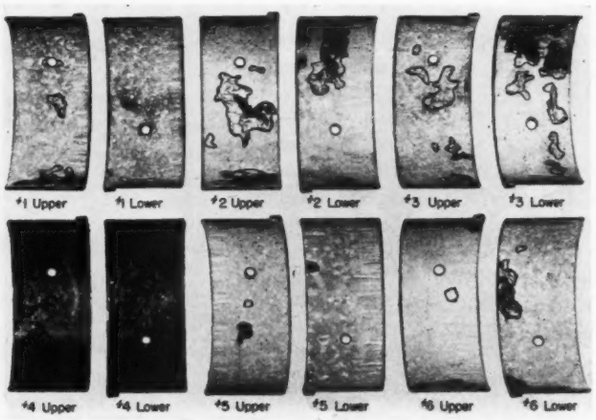


Fig. 5—Type "D" bearings after a run of only 60 hr. and 14 min. The test was stopped because number 4 bearing failed completely and was no longer serviceable

is too long, a harmful cooling effect will be set up from the ends inwardly toward the center which will be the last portion of the babbitt to cool and consequently will be in a more plastic condition than the metal on either side of it. Shrinkage and porosity is likely to occur in the last portion of the babbitt to cool resulting in an impairment of the bond, localized stresses in the babbitt, poor babbitt structure and early failure of any bearings which may be made from these sections of the tube. The areas of shrinkage and porosity may be ½ in. to 1 in. or more from each end of the tube.

It is, of course, much cheaper to use long rather than short tubes since more bearings can be made from a single tube, but the quality of the babbitt and bond is not uniform.

If good adhesion of the babbitt to the teel tube is to be obtained the surface or surfaces to be lined must be perfectly clean. The least expensive way of attempting to obtain a condition of cleanliness is by pickling; however, there appears to be certain hazards connected with this method because of differences and variables in the surface condition of the tube, that is, in the amount of rust, grease and scale which may be present. Considerable care must be used by the operator to make sure that

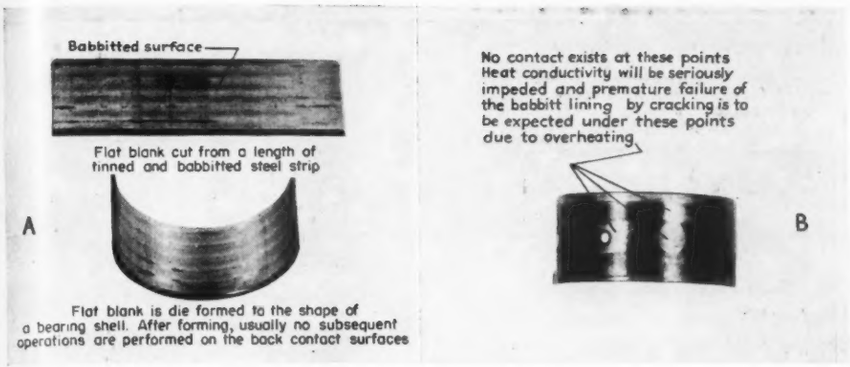
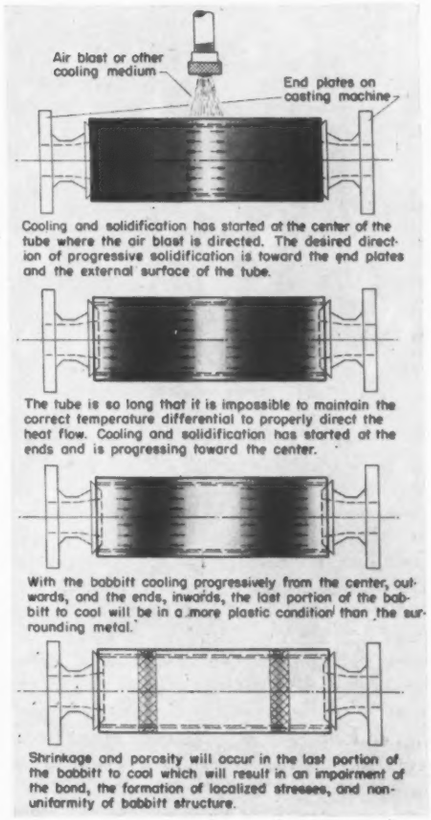

Babbitted surface
Flat blank cut from a length of tinned and babbitted steel strip
A
Flat blank is die formed to the shape of a bearing shell. After forming, usually no subsequent operations are performed on the back contact surfaces
No contact exists at these points Heat conductivity will be seriously impeded and premature failure of the babbitt lining by cracking is to be expected under these points due to overheating
B

Fig. 6—(a) Stages in the manufacture of a babbitted-strip bearing. (b) Back surface of a babbitted-strip bearing "blued-in" under 1,200 lb. pressure to show condition of contact surface

Fig. 7—Diagram showing the effect of cooling and solidification of babbitt "spun in" a steel tube which is too long


Air blast or other cooling medium
End plates on casting machine
Cooling and solidification has started at the center of the tube where the air blast is directed. The desired direction of progressive solidification is toward the end plates and the external surface of the tube.
The tube is so long that it is impossible to maintain the correct temperature differential to properly direct the heat flow. Cooling and solidification has started at the ends and is progressing toward the center.
With the babbitt cooling progressively from the center, outwards, and the ends, inwards, the last portion of the babbitt to cool will be in a more plastic condition than the surrounding metal.
Shrinkage and porosity will occur in the last portion of the babbitt to cool which will result in an impairment of the bond, the formation of localized stresses, and non-uniformity of babbitt structure.

the pickling time is adjusted to suit the particular conditions of the various runs of tubing, otherwise all the surfaces to be babbitted will not be perfectly clean and many bearings are likely to possess an inferior bond condition.

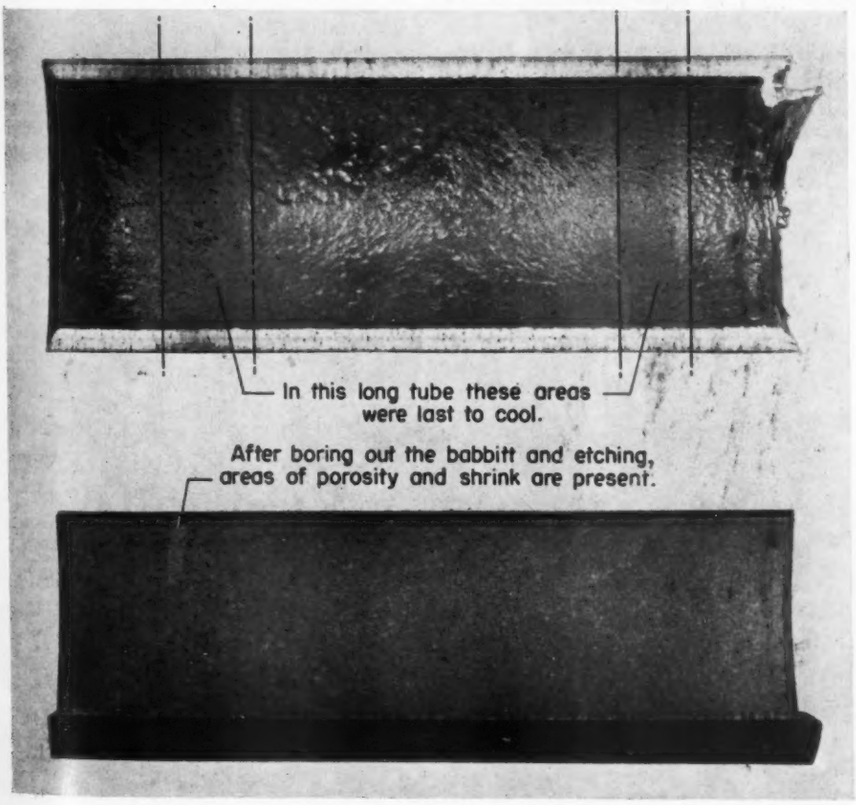
To obtain greater uniformity in the cleanliness of the steel surfaces prior to babbitting the tube may be bored, but this is more costly than pickling. When boring the feed may be coarse, about 0.030 in. or it may be fine, about 0.010 in. Which feed should be chosen?

Assuming a bearing with a finished steel thickness of 0.044 to 0.048 in., a babbitt lining thickness of 0.010 to 0.015 in., and a boring feed of 0.030 in. then the cross-section of the bearing wall will have the general appearance as shown in Fig. 9(A); this sketch is much larger than actual size. With this construction in a bearing the action of the sharp points of the "threads" may be harmful in prematurely breaking down the babbitt under load. Also with this deep cut considerable steel is removed thus weakening the back.

The same steel bearing shell that is shown in Fig. 9(A) and 11(C) is again shown in Fig. 9(B) and 11(B) bored with a 0.010 in. feed, and the points of criticism are apparently considerably improved. Boring the tube to these specifications, however, is more costly than either pickling or boring with a coarser feed.

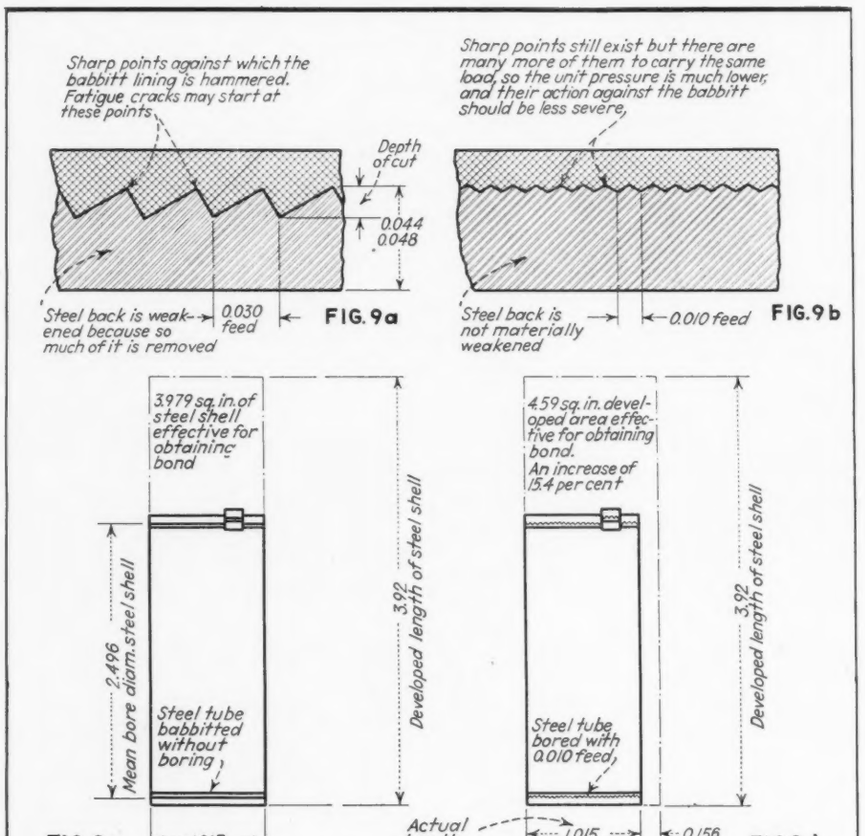
An additional advantage of the steel shell when bored with a 0.010 in. feed over an unbored and pickled steel shell is that greater bonding area is obtained in the same length of bearing. Fig. 9(C) and (D) compare graphically the increase in bonding area when the tube is bored.

Fig. 8—Showing areas of porosity in excessively long centrifugally babbitted steel tube


In this long tube these areas were last to cool.
After boring out the babbitt and etching, areas of porosity and shrink are present.

A bearing with a finish-ground back should be expected to show practically 100 per cent contact over the entire back surface, but as shown in Fig. 10, this is not always true. The poor back contacts are the result of finish-grinding the babbitted shell oversize before separating it into halves. The amount of oversize is governed by the stock removed when the shell is split. With the shell ground oversize, and the outside diameter desired is obtained by die forming, the backs are not always true cylinders.

Perfectly true backs can be obtained, however, if the bearings are ground in halves. These remarks concerning back contact pertain mainly to steel-back bearings with a wall thickness of 3/32 in. or larger. The operation of finish-


Sharp points against which the babbitt lining is hammered. Fatigue cracks may start at these points
Depth of cut
0.044
0.048
Steel back is weakened because so much of it is removed
0.030 feed
FIG. 9a
Sharp points still exist but there are many more of them to carry the same load, so the unit pressure is much lower, and their action against the babbitt should be less severe,
Steel back is not materially weakened
0.010 feed
FIG. 9b
3.979 sq. in. of steel shell effective for obtaining bond
2.496 Mean bore diam. steel shell
Steel tube babbitted without boring
3.92 Developed length of steel shell
1.015 Length of bearing
FIG. 9c
4.59 sq. in. developed area effective for obtaining bond. An increase of 15.4 per cent
Steel tube bored with 0.010 feed
3.92 Developed length of steel shell
Actual length of bearing
1.015
0.156
1.171
Developed length of bore line
FIG. 9d

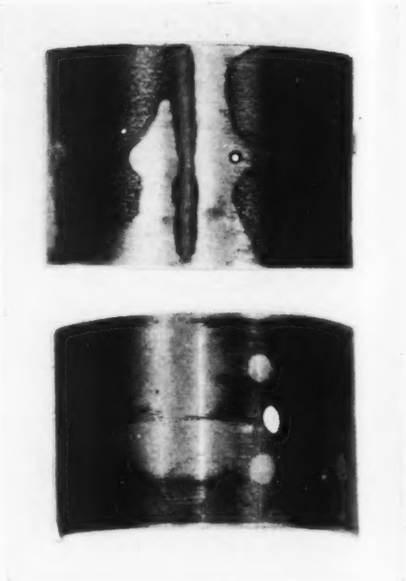


Fig. 10—Bearings made from steel tubing and the backs ground. Grinding operation, however, was performed at a point in the sequence of operations to obtain lowest cost rather than highest quality. "Blueing in" the backs shows a very poor contact

Fig. 9—Section through typical connecting rod bearing with the steel shell bored with (a) a 0.030 in. feed, and (b) a 0.010 in feed; (c) typical bearing shell babbitted without boring, and (d) shell bored with a 0.010 in. feed showing increase in bonding area

grinding the half shell is more expensive than grinding the shell oversize in the full, followed by separating and forming, but a truly round back contact is obtained and maximum heat conductivity is therefore assured.

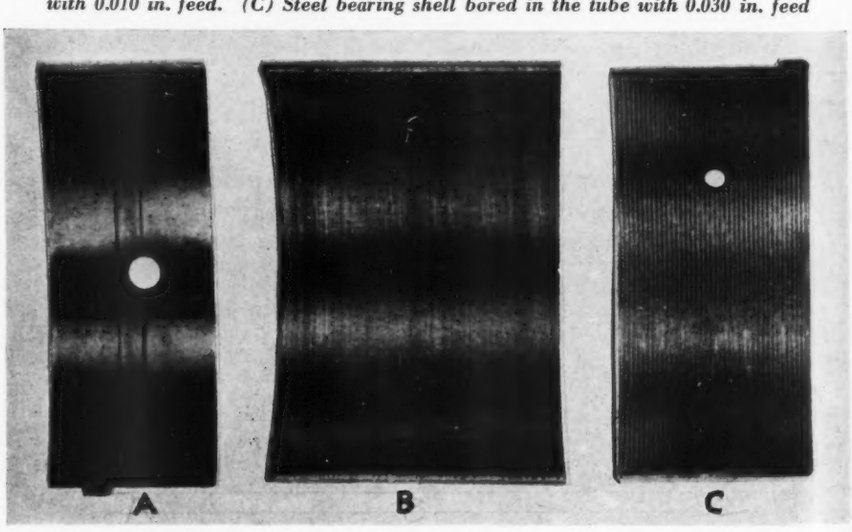
It is to these various elements of babbitted-strip bearings, bearings made from centrifugally babbitted tubes, tube length, preparation of the tube bore for babbitting, and condition of the backs that the differences in the condition of the bearings shown in Figs. 2, 3, 4, and 5 are attributed, and while the bearings described have all been lined with tin-base babbitt, the same conditions exist with respect to bearings lined with cadmium-silver and high-lead babbitt.

The specifications to which bearings are purchased, or at least on which tentative quotations are obtained usually consist only of a drawing showing the physical dimensions required and the materials desired. Very seldom is there any mention of these vital elements involving how the desired materials are to be fabricated into a bearing and which enter into the matter of cost and bearing life expectancy.

A condition exists wherein bearings are too frequently procured on the basis of competitive prices which are founded on incomplete specifications. The cheaper product often fails to give satisfaction. The user, for one reason or another, may not be familiar with the possibilities of increasing the capacity of his bearings by methods which are readily available, although at a slightly higher cost, and is likely to change to a much more expensive type of bearing material or get into costly design changes involving associated parts.

The cure for this condition is sufficient knowledge of the bearing operating conditions, which may be generally classified as load, speed, temperature, and lubrication, and then to match against this knowledge the proper materials of bearing construction in combination with how those materials are to be processed to obtain the proper bearing capacity and finally to include both in a comprehensive specification.

Fig. 11—(A) Inside surface of steel shell prepared for babbitting by pickling. Note the smoothness of surface. (B) Steel bearing shell bored in the tube with 0.010 in. feed. (C) Steel bearing shell bored in the tube with 0.030 in. feed



ELECTRONIC CONTROL

Gaging and Registering Applications

R. A. POWERS
Vice-President and General Manager, Electronic Control Corporation

Application of photo-electric cells and amplifiers to measure pieces, control temperature, inspect surfaces and control registration in printing and packaging machines

Fig. 1 Close-up view of operator placing a valve stem between the hydraulically driven dies of a resistance heater. The photo-electric cell housing can be seen as the tubular structure, while the small air blast from the tube can be seen blowing the smoke away from the oil covered tip of a valve as it comes up to heat

IN THE preceding articles which appeared in various issues of *Product Engineering*, both simple and special applications of photo-electric systems and standard light relays were described. This concluding article will deal with photo-electric equipment which requires a more careful consideration of light sources, photo-electric cell housings and optics in the design and installation of electronic control apparatus to perform efficiently unusual operations.

Since control by means of a beam of light is frictionless, it is natural that this method should be used for measuring dimensions of objects where limits are of the order of 0.0001 in. Thousands of pieces can pass through a beam of light and not destroy the accuracy of the gage. Beams of light with photo-electric cells are used for measuring and grading for selective fit objects having less than 0.0001 in. dimensional variation. An auxiliary optical system and photo-electric cell can be installed below a locating block so that in the event wear takes place or should dirt accumulate the gage will be inoperative until the faulty condition is corrected.

Naturally, in measuring devices the amount of light variation, reaching the various photo-electric cells which control automatic rejection at various stages, is of a very low value. So small is this variation in light in one particular gage which is used for measuring and grading to 0.0001 in. that the image shadow cast by the object being measured, as compared with the illuminated portion, cannot be detected by the unaided human eye. To insure accurate results when measuring to these close limits a change of 0.0001 in. in the object size must be optically magnified so that the change will cause total eclipse of one, or illuminate totally the cathode of another, photo-electric cell. Since the cathodes are approximately ½ in. wide the change in the original object is magnified about 5,000 times. Light intensity decreases by the square of the magnification, therefore, it can be appreciated that the light intensity change occurring at the photo-electric cell is negligible, as too much light cannot be used in illuminating the surface of the object being measured. A large total illumination on the subject being measured would increase the temperature and destroy the accuracy of the gage.

Automatic gages are now being designed for the inspection of automotive engine pistons. One of the stages of inspection is to determine if all the oil holes in the lower ring groove have been cleanly drilled to insure good lubrication of the cylinder wall. The complete inspection device will mechanically lower a series of photo-electric cells, one for each oil hole, down over the piston and at the same time a light source consisting of a 15 candlepower automobile headlight bulb will be inserted into the piston. The light traveling through the oil holes, which are approximately 1/16 in. in diam., will impinge upon the sensitive area of each photo-electric cell. If any one of the photo-electric cells does not receive the correct amount of illumination, the common photo-electric amplifier will close a relay circuit automatically rejecting this piston. In automatic inspection for oil holes anywhere from five to nine photo-electric cells may be connected to one sensitive amplifier.

The frequency response of the caesium emissive type photo-electric cells is predominant in the infra-red band of the spectrum. The maximum response of the average photo-emissive cell is in the invisible region between 8,000 and 10,000 Angstrom units. Consequently, this cell when correctly used performs the function of an accurate tempeature indicator and control.

To obtain satisfactory photo-electric temperature control or indication all

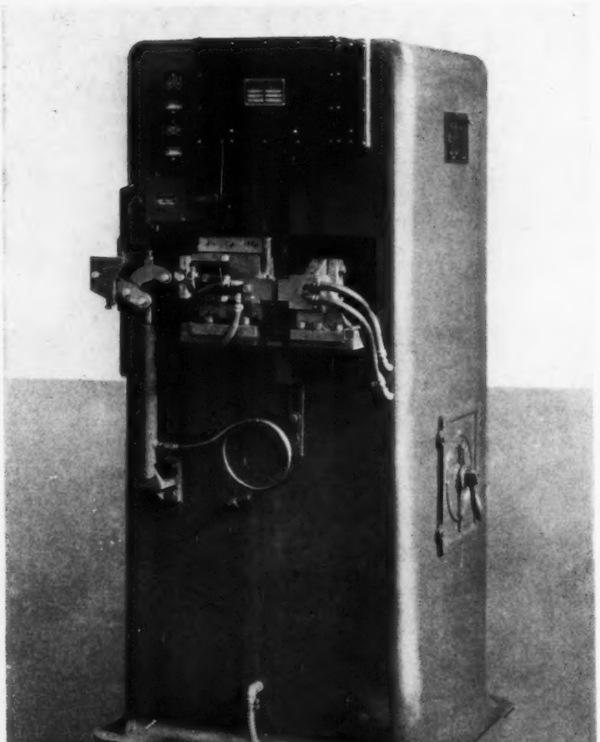


Fig. 2—Complete valve tip heater using resistance heating and photo-electric temperature control. Initiating switch is shown on the floor. In this early model the photo-electric cell was mounted in the black tube attached to the bottom of the photo-electric amplifier

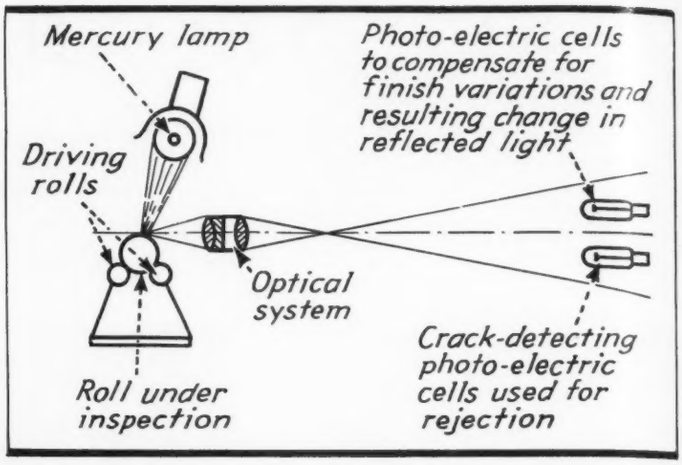

Mercury lamp
Photo-electric cells to compensate for finish variations and resulting change in reflected light
Driving rolls
Optical system
Crack-detecting photo-electric cells used for rejection
Roll under inspection

Fig. 3—Optical system and approximate set-up for photo-electric inspection of rollers for cracks and flows. A mercury lamp illuminates the surface of the roller. The optical system picks up the image of the brightly illuminated surface and projects it back within the housing to the photo-electric cells. The cells in the upper group are used to compensate for variations occurring in the metal finish and resulting change in total amount of reflected light, the lower cells are used for the rejection. The mercury lamp producing modulations in light intensity, according to the frequency of the supplying power, makes a.c. amplification possible

ambient light, such as the variations in extraneous illumination between day-time and night-time, must be excluded from the light sensitive area of the cell. Several means have been introduced to do this. With an optical system side light may be entirely excluded, but the heated object under inspection may reflect to the photo-electric cell the variations in normal room light changes. Because infra-red energy is very poorly reflected by the average dark objects or black machinery found in machine shops, it is most desirable to combine an optical system, which will limit the area of light pick-up, with a filter which will exclude all light except the invisible infra-red energy.

Thermal Inertia Eliminated

The photo-electric cell when properly applied has many advantages in temperature control and indication over the conventional thermocouple or other similar devices. The photo-electric cell completely eliminates the problems encountered with the thermocouple caused by thermal inertia. The inertia present, being merely that of light, the photo-electric cell is almost instantaneous in response.

As a result of these advantages, photo-electric means of control are used in many heat-treating and annealing operations where the heating cycle is extremely rapid. Fig. 1 and 2 show a resistance heater for heat-treating the extreme tip of valve stems. The operation of this unit is simple. The operator places the top of the valve stem between the hydraulically driven dies which close upon the section to be heated. These dies are the terminals of the secondary of a welding transformer, as soon as sufficient pressure upon the dies has been built up a pressure switch energizes a welding transformer primary contactor. The top of the valve stem is brought from room temperature to 1,800 deg. F. in approximately ½ second. Heat is generated rapidly and a small amount of over-timing will result in burning the tip of the valve stem, while a short timing results in insufficient heating. Only the photo-electric cell can accurately turn off the heating current when the correct temperature within plus or minus 20 deg. F. is reached. The complete device consists of the resistance heater, the clamping mechanism and the control. Accurate temperature maintenance is made possible with photo-electric cells and their associated amplifying tubes. An infra-red filter eliminates the necessity of continually changing adjustments of photo-electric amplifier sensitivity to overcome changes in ambient light.

Similar photo-electric cell devices are used for other heating operations, including the resistance heating of steel shells of spark plugs as they are hydraulically pressed over the ceramic insulator, and resistance heating to anneal at 900 deg. F. the king pins of front axles for motor cars.

The applications described in the preceding paragraphs of the more exacting requirements of photo-electric equipment make use of transmitted light. There is another large field in which reflected light is used with photo-electric equipment such as color matching, inspection of surface for flaws or cracks, following predetermined charts, registration control from printed cards, and even alarm systems are operated by reflected light from objects passing into forbidden territories.

Inspection of Rollers

Some feeble attempts have been patented which embody photo-electric means of inspection of rollers for roller bearings, but in all of these attempts only a small linear surface of the entire roller has been inspected at one time. As the roller is revolved the optical system picking up the light from the surface is moved through the length of the roller so that each portion is inspected. While this system offers some advantages over the human eye, it is not rapid enough, and will not compensate for variations in colors occurring because of the surface variation of the various rollers.

Recently a photo-electric system has

been employed which inspects the entire length of the roller at one time in which it is necessary to revolve the roller only one revolution for a complete inspection of its surface for cracks, flaws, chips, rough spots or other irregularities which if present make it desirable to reject the roller. This type of photo-electric inspection device is equipped with a compensating photo-electric system so that over-all variations in reflected light, because of change in color or change in quantity of reflected light resulting from variations in the finish or in the steel from which the roller has been made will automatically compensate themselves.

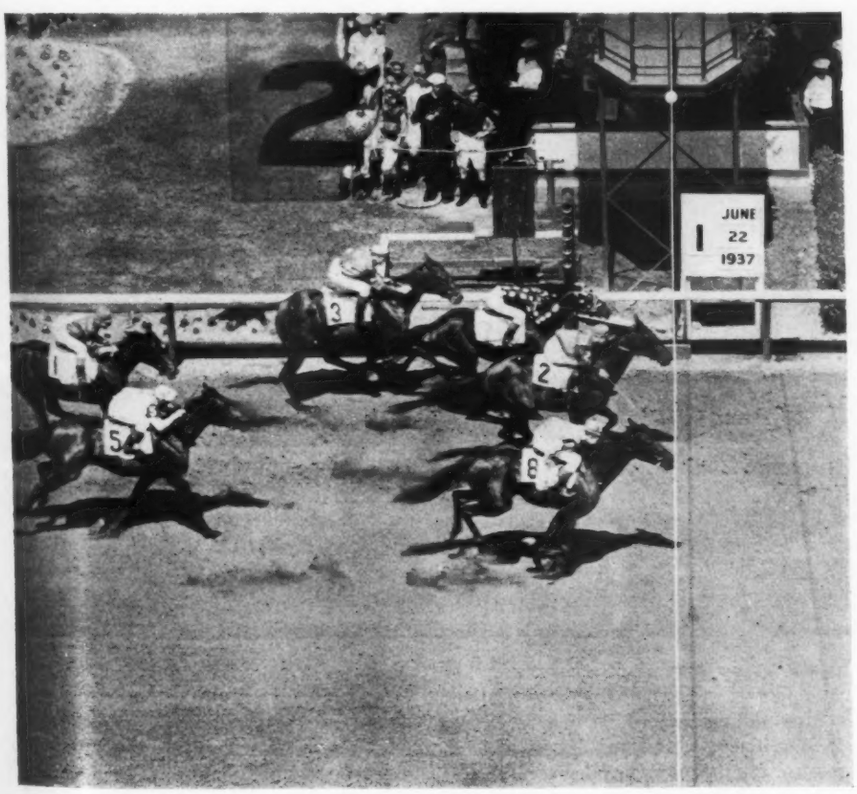
Control of Registration

The optical system used in conjunction with the photo-electric cells, amplifier, detector, and final amplifier for inspecting the entire linear length of a roller is shown in Fig. 3. To insure speed of operation the output stage of the photo-electric amplifier used a gaseous tube with a d.c. potential applied to the anode. Firing, because of a crack or a flaw, initiates a rejection solenoid circuit until a new roller is indexed into the focal point of the optical system. A limit switch opens the anode circuit when a new roller is indexed into position allowing the rejection solenoid to return to normal until a crack or flaw appears before the optical system and the resulting photo-electric cells. The average roller which is 1½ in. in length and ¼ in. in diam. can be readily indexed into the fixture, inspected, rejected, or passed and another roller indexed in less than one second, providing the mechanical equipment is properly designed.

In the near future photo-electric inspection of surfaces will open up an entirely new field for automatic control, and the photo-electric cell will actually become an "Electric Eye," because it not only compensates for variation in original surface but it also picks out cracks and flaws which cause less decrease in illumination of photo-electric cells than do the variations resulting from changes in metal structure.

Control of registration by means of reflected light from printed paper in automatic packaging machines is not a new application, however, the possibility of having die sinking machines follow the original lines of a drawing offers a promising field for photo-electric adaptations. At present photo-electric cells used in what might be called a differential circuit are accomplishing automatic control from predrawn charts. Three-way control is obtained by means of two photo-electric cells, or one photo-electric cell with a split or dual cathode. Control is accomplished through relay or tube circuits. As long as one cathode of the cell is illuminated and the other cathode is dark no control results, but in the event that the previously illuminated cathode becomes dark control operates in one direction; while if the previously darkened cathode becomes illuminated, control results in the opposite direction until a position is found at which no "hunting" occurs. This type of differential circuit is being used for measuring, grading, sorting and also for controlling registration location of web in presses and automatic line following operations.

Fig. 4—Typical Camera Finish Picture of horses finishing almost in a dead heat. The photo-electrically controlled camera made it possible to separate the two horses as they struck the finish wire



Removing Human Equation

Aside from industrial applications of photo-electric cells and electron tubes, but of interest to many people is the application of photo-electric cells, associated amplifiers and relays for the operating of accurate Camera Finish Equipment as used at America's leading race tracks. A curtain of light is projected across the track just preceding the finish line. A picture is automatically snapped when a horse, with nose on the finish line, intercepts the curtain of light. Fig. 4 is a typical picture produced through electron tubes and photo-electric cells. The picture is completely finished in 90 seconds after the horses cross the line, and an 8x10 in. enlargement is placed in a cable car and delivered to the judges stand. The human eye never could detect the winner in a finish as close as this. In the past the judges would have ruled this close decision a "dead heat." The public would never be satisfied because of their inability to have seen the finish as the judges saw it. Now the judges receive the picture within 90 seconds, and within five minutes after the race a group of enlargements are posted throughout the grandstand so that the public may see how the judges obtain their decision. This is just another photo-electric application that insures public confidence and reliability of electronic equipment over the not infallible human equation.

Many photo-electric applications, electron tube applications, optical and associated equipment have fallen by the wayside because the mechanical engineer did not fully appreciate the involved problems of electronics and optics associated with his desired use of tubes. Moreover, photo-electric and mechanical problems have also suffered because the specialist in electronics and optics did not know product requirements or shop practice. To obtain the best results from either built-in to product or individual photo-electric equipment the electronic engineer should consult and combine his efforts with the mechanical engineer. The cooperation of engineering talent on all sides of a special problem cannot be too strongly stressed and encouraged.

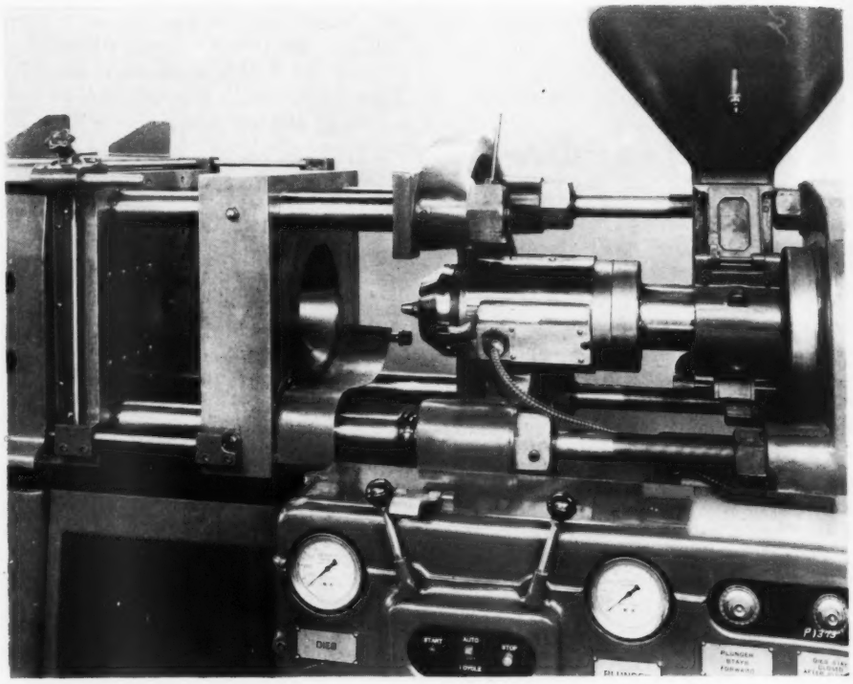
Modern Designs

Plastic Molding Machine Has Induction Heating

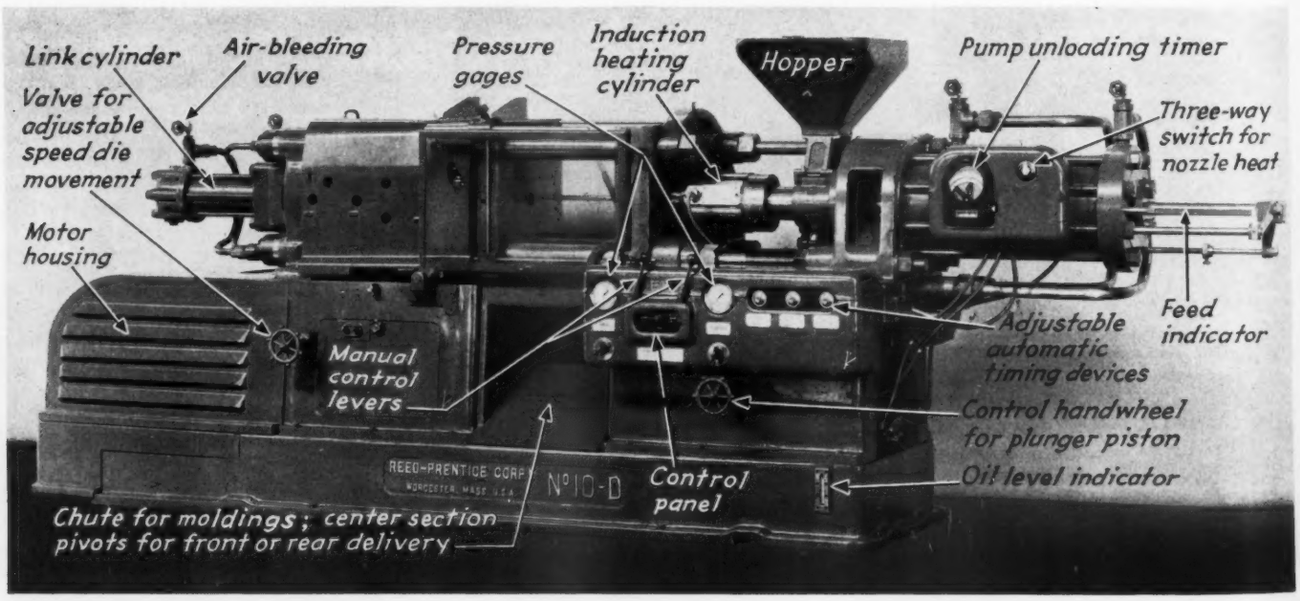
HYDRAULICALLY operated throughout, the latest Reed-Prentice plastic injection molding machine, Model 10-D, has a specially designed inbuilt heating unit of the induction type. Coils of induction heating cylinder are wired so that at cold starting they are in parallel and heating effect is quadrupled. When temperature is within six degrees of setting, coils are automatically switched to series connection. Should temperature during machine operation drop six degrees, coils will be automatically switched to parallel.

Mold locking pressure of 175 tons is supplied by a cast steel toggle-link mechanism. Toggle end of the machine is adjustable through a screw mechanism. Entire injection end of the machine is also adjustable. Machine is arranged for manual, single-cycle automatic or full-automatic operation.

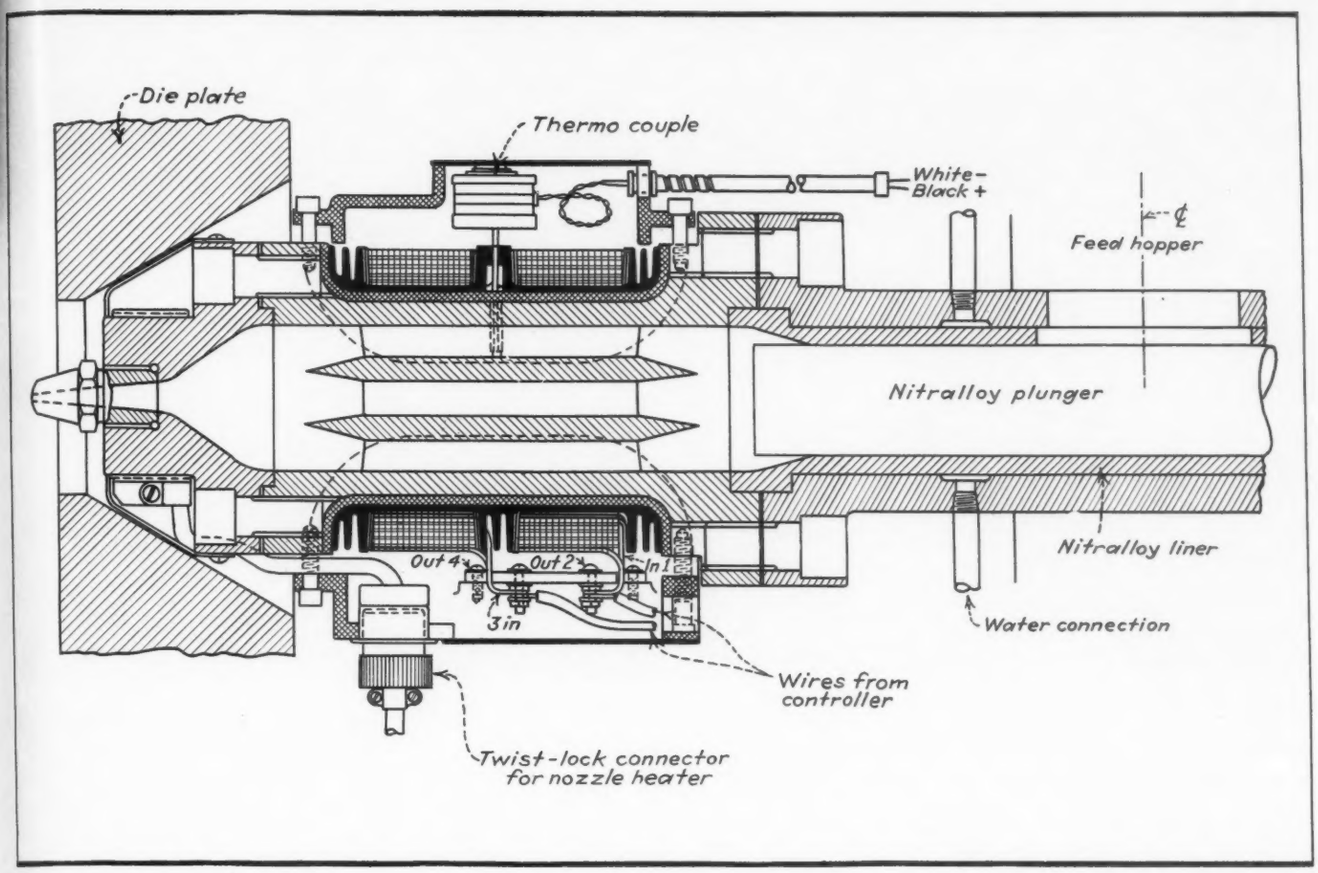
Safety latch on pilot valve lever prevents accidental starting; and further protection is afforded by a Vickers interlock valve which closes the hydraulic circuit when the safety door is opened.



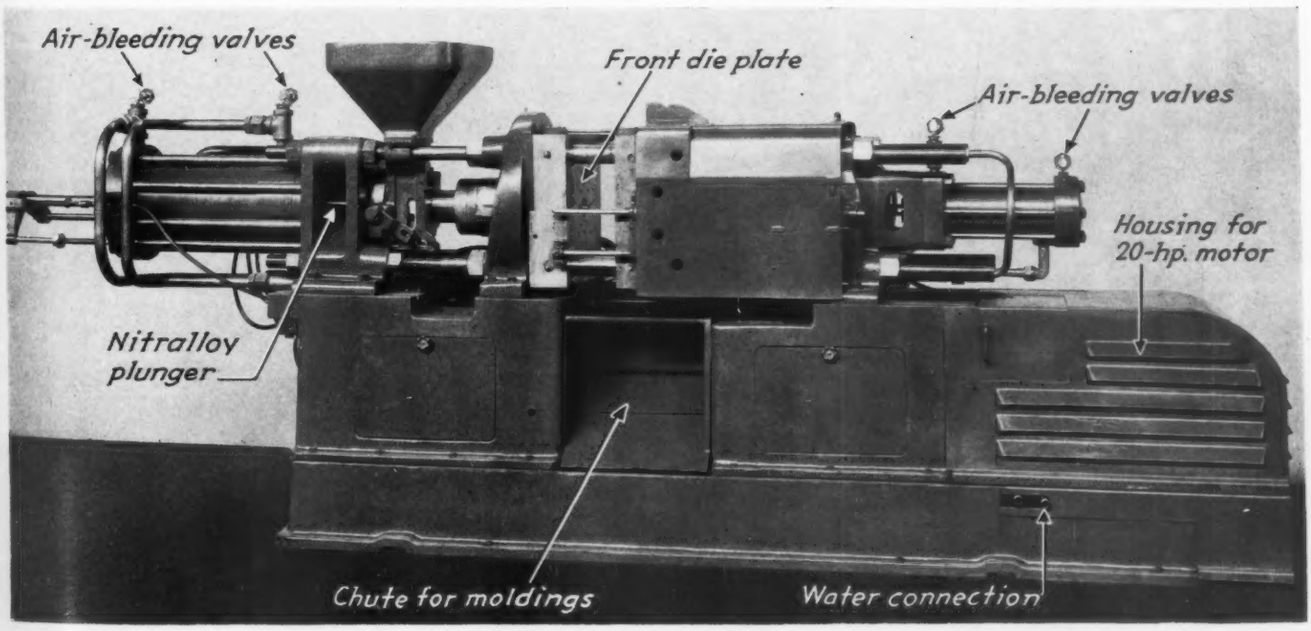
Rapid, uniform heating is provided by the induction heating cylinder through which the material fed from the hopper is forced by the Nitralloy plunger.



On manual operation, the machine is controlled by two levers: one for mold closing, and the other for injection cylinder operation. A selector switch on the control panel governs single-cycle or full-automatic operation. During automatic operation, the machine is controlled by three timing switches adjustable from 0.2 to 120 sec. One times the period of pressure on the plunger, the second determines curing time, and the third sets the length of time the molds are open. On single-cycle automatic operation, the plunger timer and curing timer only are used for machine control.

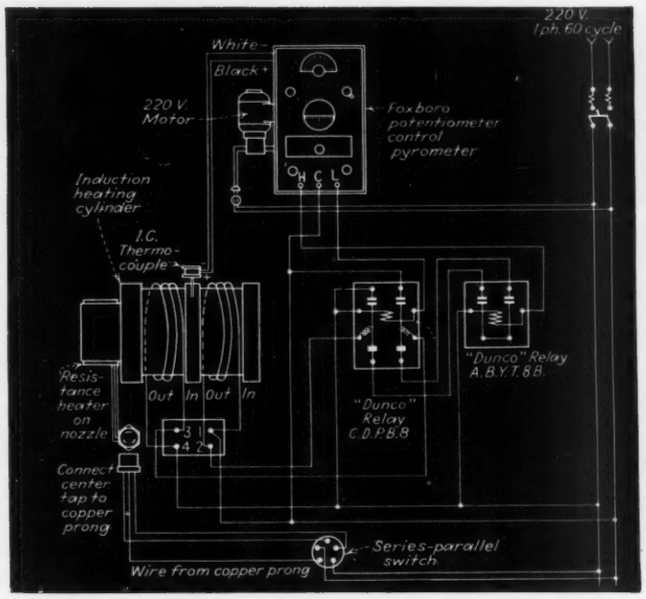


Cross sectional view of the induction heating unit on the machine. The cylinder, which has small-diameter holes through which the material is forced, also serves as the induction coil core. Heat is generated in the steel core itself, and the ratio of heating surface to heated surface is very large, thus practically uniform heating of the material is obtained. With this type of cylinder, it is possible to place the thermocouple closer to the material and thus reduce lag between actual material temperature and temperature which is recorded at point of control.

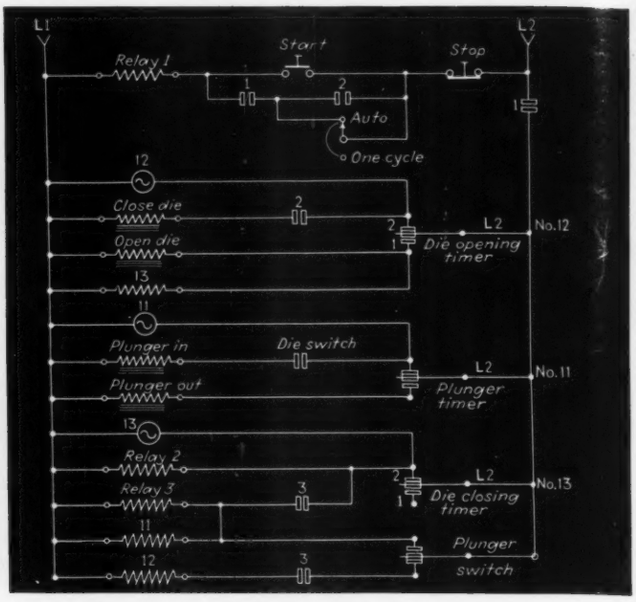


Rear view of machine showing water connections. Inbuilt Harrison radiator water-cools hydraulic oil stored in a reservoir of 70 gal. capacity in the cast iron base of machine. Injection feed cylinder has a Nitralloy liner and plunger is also of Nitralloy steel. Stationary die plate is cut from a solid steel plate 4⅞ in. thick. Movable die plate is a steel casting 4½ in. thick, ribbed for strength and provided with 10½ in. bronzed-bushed bearings on tie bars. Knockout device removes molded pieces when machine is operating automatically. Ejection chute adjusts for front or rear delivery.

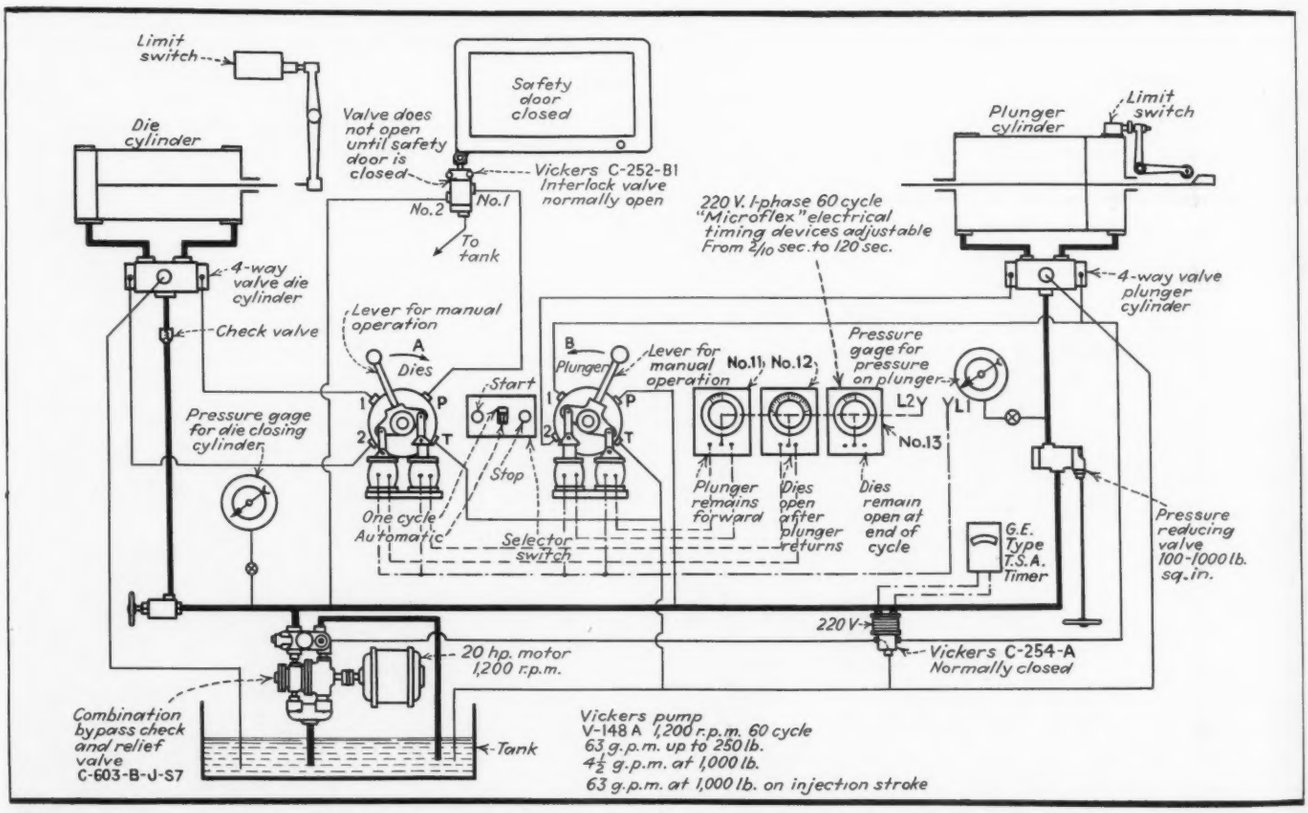
Modern Designs—Plastic Molding Machine—*continued*



Induction heating circuit automatically shifts coils from parallel to series connection when temperature reaches six degrees below control setting, and shifts coils back to parallel connection when temperature drops below six-degree limit.

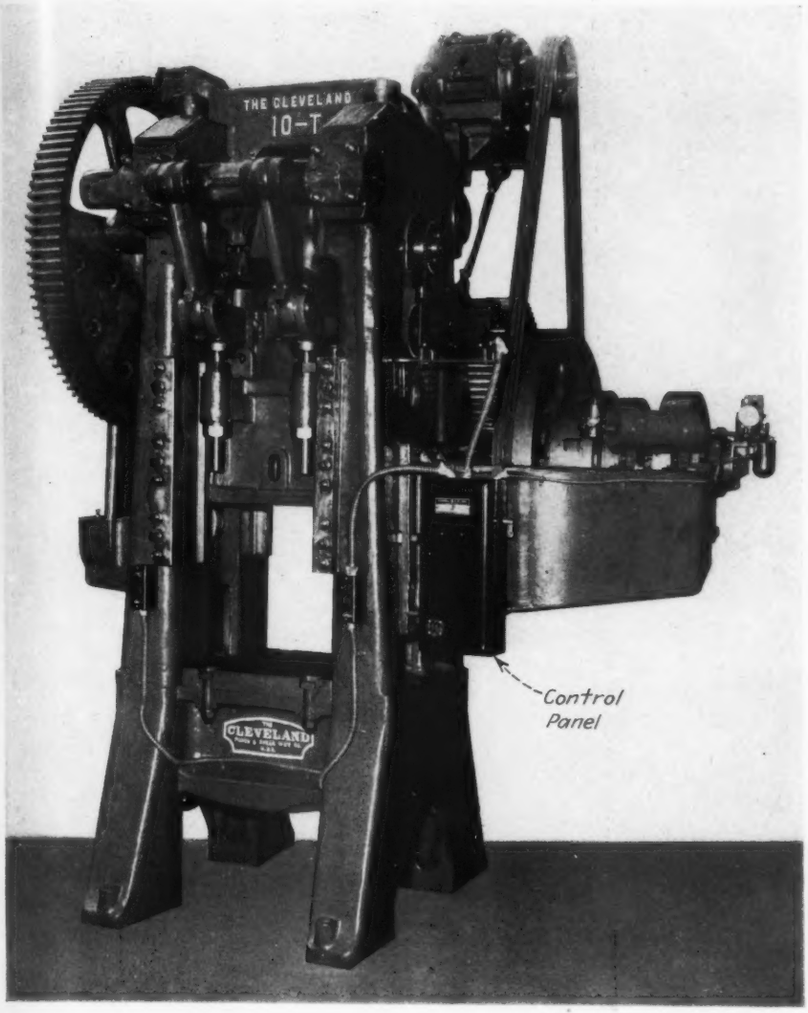


Control panel, operating on 220 volts single phase a.c. permits one-cycle automatic or full-automatic operation. On full-automatic operation, machine is controlled by three timing units; on one-cycle operation only two are used.



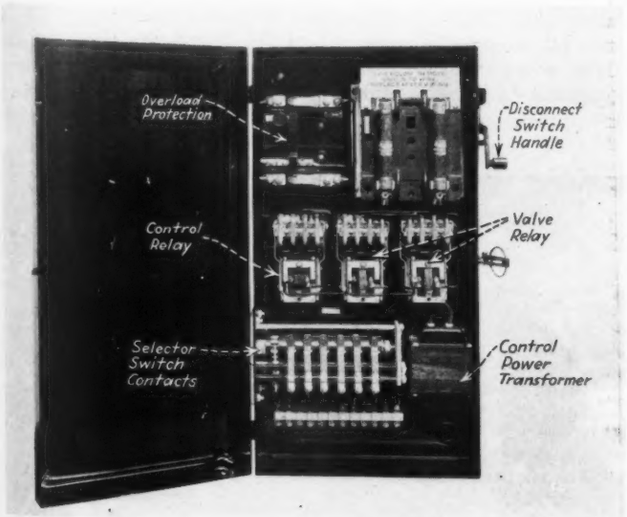
Hydraulic pressure is furnished by a Vickers combination pump direct-coupled to a 20-hp. motor. The pilot line, which carries oil under pressure to the valve controlling the injection stroke, is in series with a solenoid-operated interlock valve, normally closed. When the die-plates close, a limit switch on the die cylinder energizes the solenoid which actuates the pilot valve that starts the injection stroke, and also opens the interlock valve so that oil under pressure in the pilot line prevents the pump from unloading. This makes available full pump volume at maximum pressure for a fast injection stroke. The interlock valve remains open until the timer, set for a required time of injection stroke, times out; then the valve closes and the pump unloads. Die movement can be slowed down by manual operation of globe valve.

Modern Designs—Safety Control Prevents False Operation

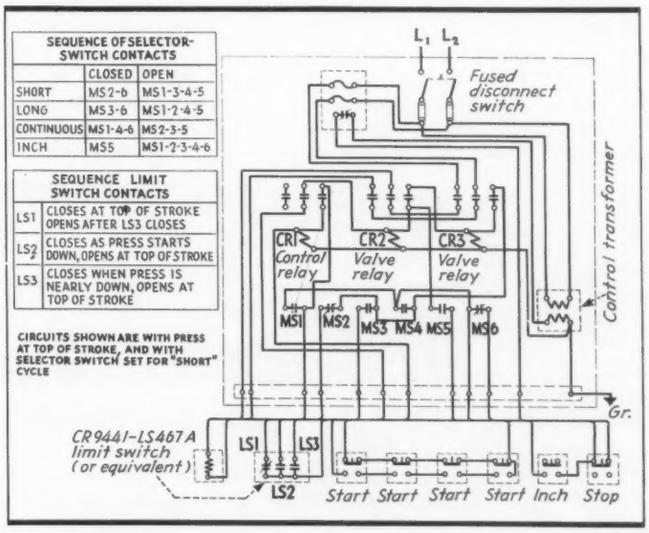


Equipped with an electrically controlled, air operated friction clutch with four station selector, this press, manufactured by the Cleveland Punch and Shear Works, is so designed that when force is exerted, it is carried directly against the steel tie rods of the frame through the straightening links and the rocker shafts, thereby relieving the crankshaft of the blank-holding strain. Press has both inner and outer slide, with the outer slide functioning to hold the material securely while the inner slide performs the blanking or drawing operation.

Magnetic control panel, rotating cam-type limit switch and oil-proof push-button stations combined, form the General Electric control system used on this press. Four different operations from "continuous stroke" to "inching" are possible. Hazards from wiring failures caused by severe vibration and oil have been reduced by a specially designed control transformer which permits arrangement of the control circuit so that one or more grounds at any point in the system cannot energize the solenoid or cause it to remain energized beyond the time dictated by normal system functioning.

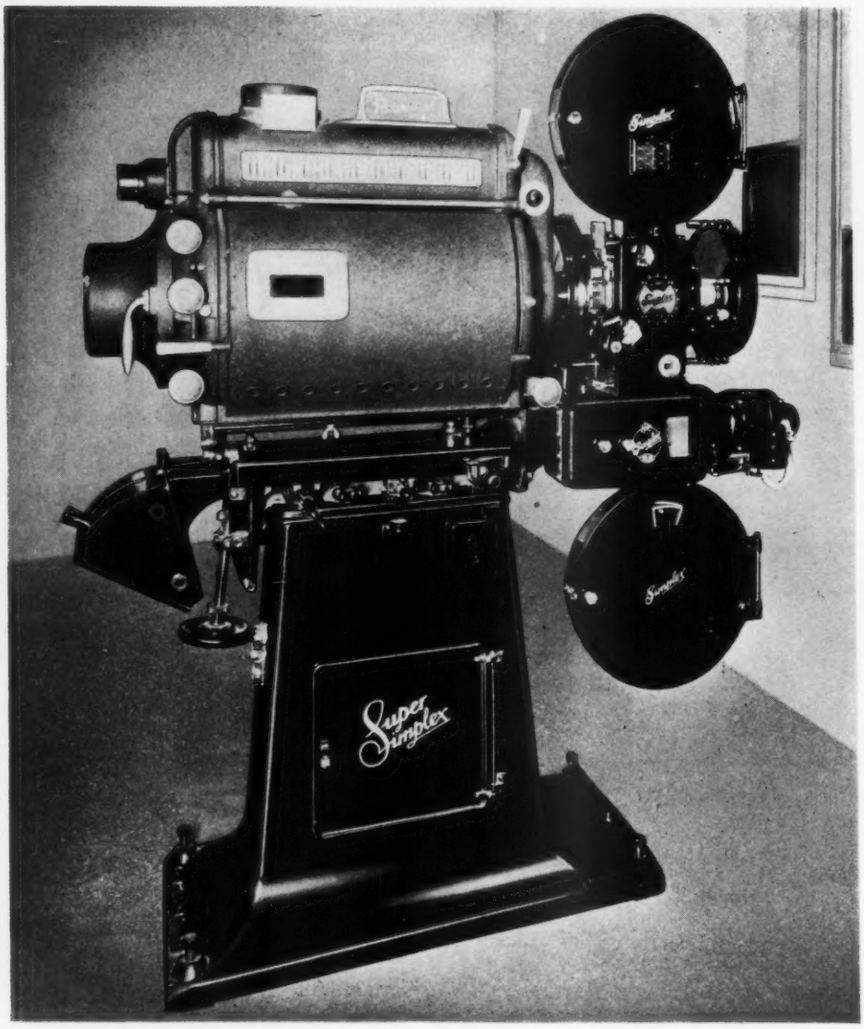


Rotating cam-type limit switch contacts are opened by positive cam action, minimizing the possibility of the press continuing to run because of the failure of contacts to open at the proper time. Installation and maintenance expense, aad the possibilities of wiring failure are reduced through the use of a minimum number of external control wires.

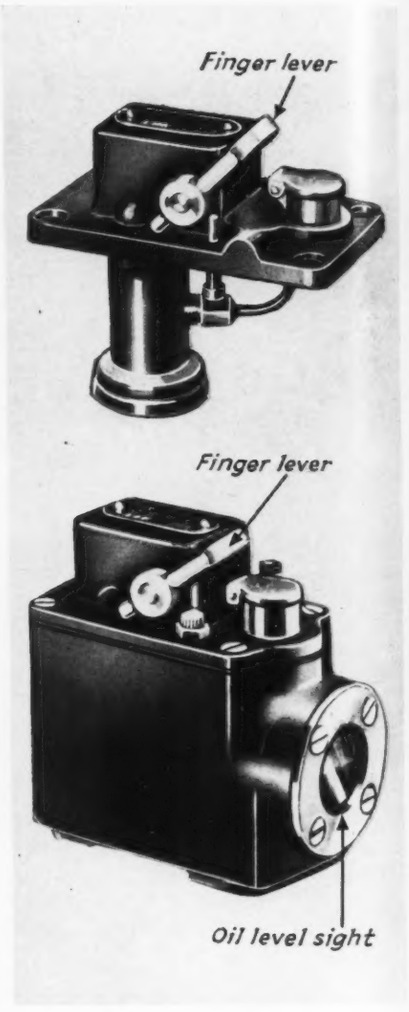


Two sets of contacts are provided on each side of the solenoid. Should several grounds occur in the connection, the solenoid cannot be energized unless the control contacts are closed. Thermal relays in the solenoid circuit provide protection against failure of the solenoid to seat. A fuse disconnect switch interlocks with the control panel door.

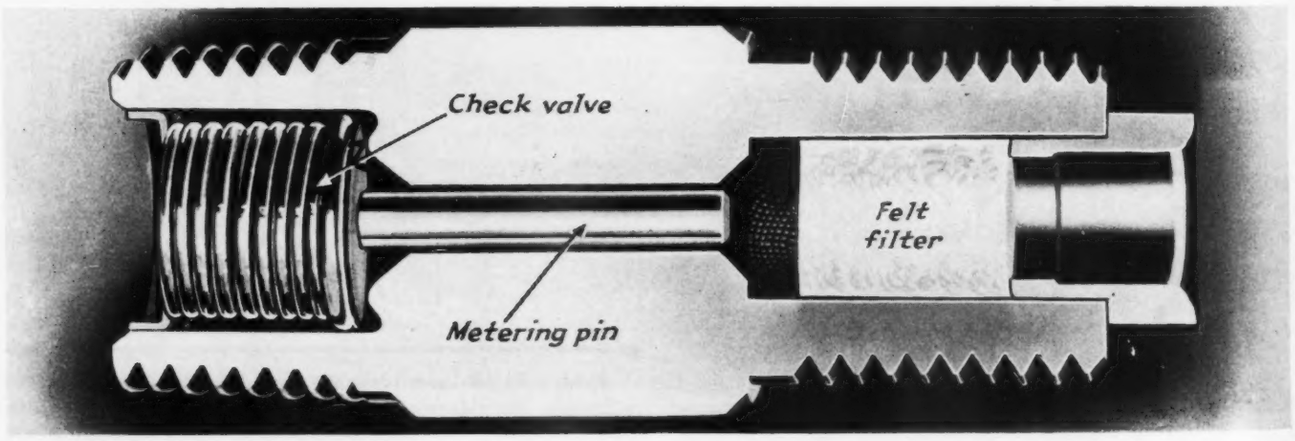
Modern Designs—Simplex Projector Has Metered Lubrication



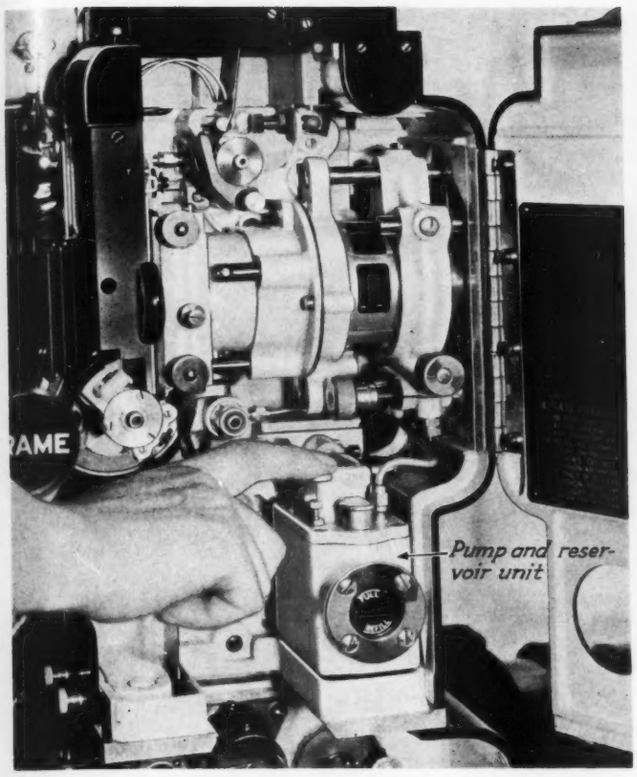
Built-in automatic lubrication as an integral part rather than as an accessory, was designed into the new Simplex projector, Model E-7, by the International Projector Corporation in cooperation with Bijur Lubricating Company engineers. This centralized pressure-lubrication system, which was especially adapted to machine requirements, consists of a lubricator pump, oil reservoir, distribution line and four meter-units. Improved projection is assured by synchronized front and rear shutters and a redesigned film gate.



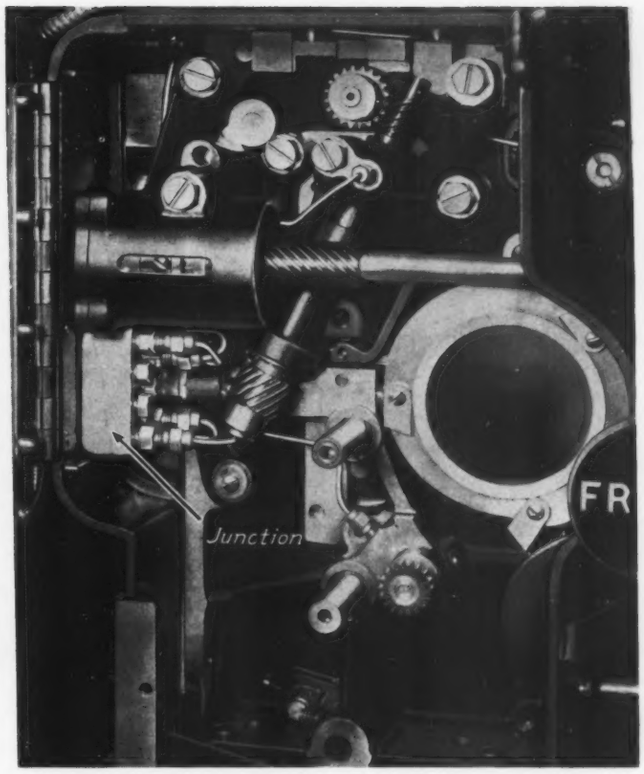
Depressing finger lever raises the piston and the correct amount of oil is forced into the distribution lines. This "one-shot" lubricator has a built-in filter and is provided with a window for visual check of oil level. Reservoir has ¼ pint capacity and an oil level check sight.



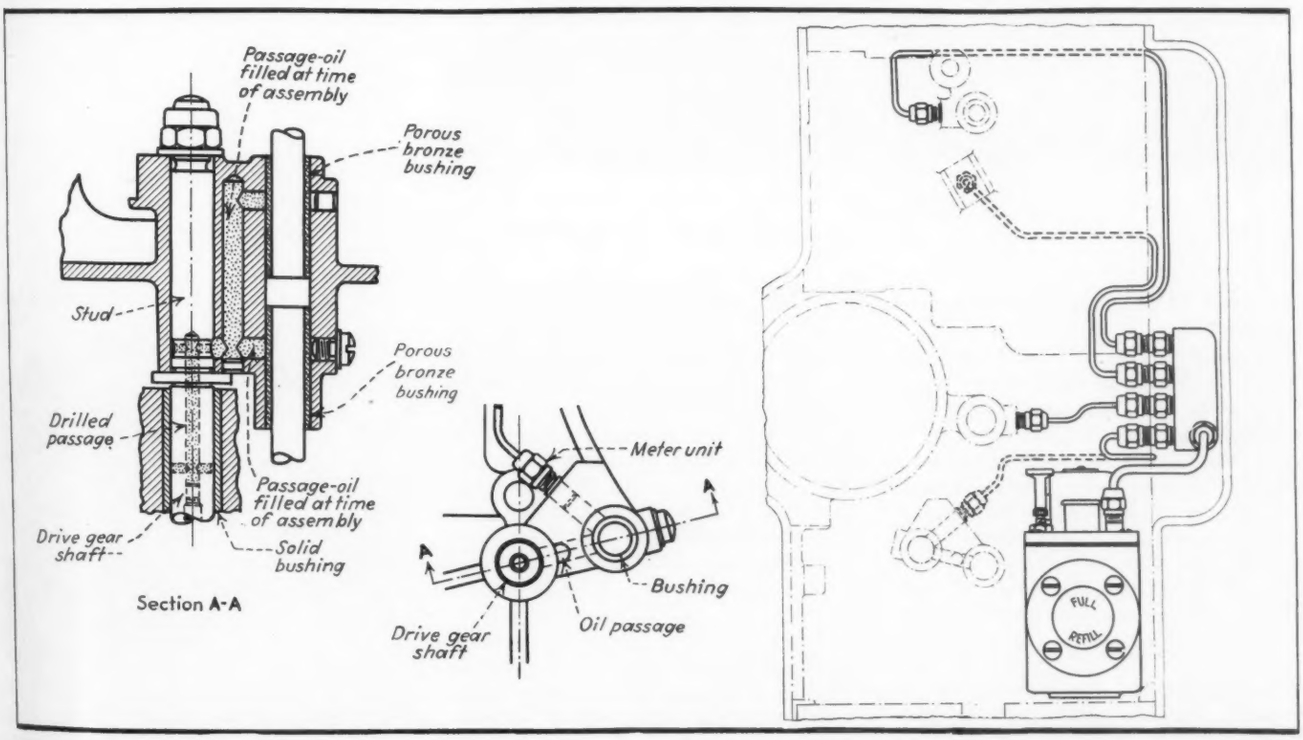
Meter unit, installed in the feed line, automatically proportions the correct amount of oil to each bearing. Clearance between metering pin and passage wall determines rate of oil flow. A check valve prevents drip and maintains tubing system full of oil between pump operations. A felt filter, built into the meter unit, provides secondary filtration of the oil.



Interior view of the right side of the projector shows compact installation of the lubricator pump and distribution system. Reservoir is 2 in. wide, 3 7/16 in. long, and 2¾ in. high. Lubricator pump, developing 35 lb. per sq.in., was redesigned in order to mount the pump-reservoir unit in a limited space.

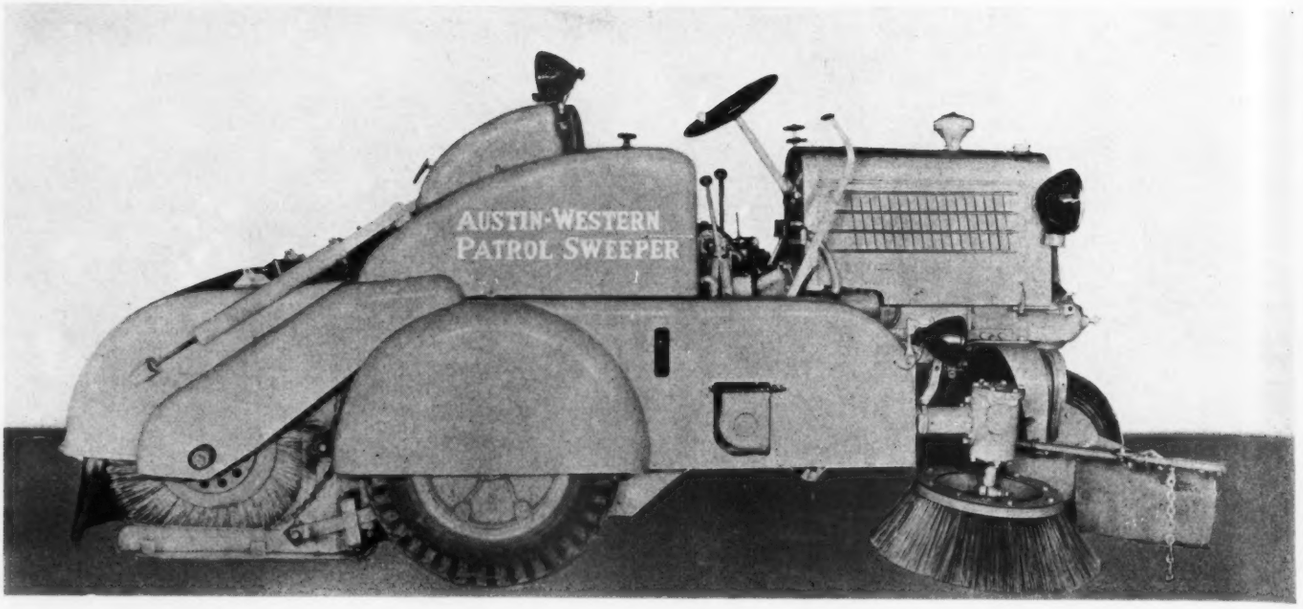


Junction and branches are located in front of projector housing, as shown in this left side interior view. Meter units are finished in chromium and feed lines in aluminum to blend with interior finish. Depression of the pump lever forces 3/10 c.c. of oil through the distribution system.



Schematic diagram of oil distribution to projector bearings by this automatic lubrication system. Single feed line from pump and reservoir unit carries required amount of oil to the junction from which point oil is fed through copper tubing 3/32 in. outside diameter to the four meter-units. Two of the meter-units service two bearings each, a total of six bearings being lubricated automatically with a predetermined amount of oil by one shot of the midget pump.

Modern Designs



Threefold objective in restyling the Austin-Western Patrol Sweeper was to improve appearance, facilitate maintenance and lessen difficulties in keeping working parts and exterior clean. As designed by Austin-Western engineers the machine met all service requirements at low operating cost but gave the impression of being an assembly of stock parts. Better appearance was obtained by lowering the radiator, shortening the intake pipe and eliminating all projecting units. Machine was redesigned under the direction of F. D. Wilson, chief engineer, cooperating with Glenn W. Tammen of Designers for Industry.

RANDOM JOTTINGS ABOUT NEW DEVELOPMENTS

Synthetic plastic is used in the new Ebolite halftone printing plate manufactured by the American Process Corporation, Chicago. Tests of the plate by the Chicago Graphic Arts Federation showed economy in first cost, good wearing qualities, light weight with resultant saving in postage, and faithful reproduction in 100, 120 and 133 line screen. The shoulderless plate permits new effects in layout and typography.

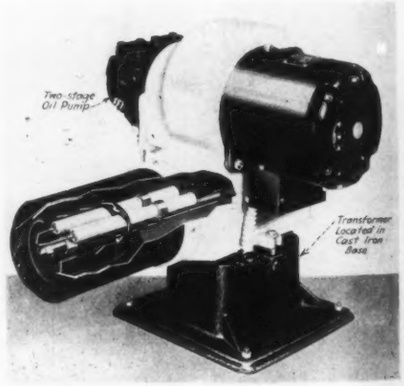
* * *

Accelerated tests, calculated to be equivalent to four years' service in sand-laden sea water have shown that a new baked-on coating system, based on a Bakelite heat-reactive varnish, will protect ship propellers from corrosion, abrasion and electrolysis.

Photrix electronic timer, which can be set to a minimum of 0.2 sec., enables operator to control exposures in the split-second region with as much accuracy as in the usual 5-20 sec. range. The enlarger or contact printer is plugged into the timer, which automatically opens the circuit after the time of exposure determined by the selector switch.

* * *

An oxygen cylinder of nickel-chromium-molybdenum steel, which was developed by the British for mine rescue work, weighs less than six lb. yet contains 10½ cu. ft. of free gas at a test pressure of 3,360 lb. per sq. in. The cylinder, if it had been made of ordinary steel, would have weighed more than twice as much for the same capacity.



Newly designed pressure-type oil burner, product of American Radiator Company, has two-stage fuel pump, sirocco-type fan of aluminum, and ⅛ hp. Ohio motor direct connected, with flexible coupling between motor shaft and pump. Fuel pump has built-in Monel strainer.

DESIGN-STRESS DIAGRAMS

For Alternating Plus Steady Loads

J. B. KOMMERS
University of Wisconsin

Method for determining safe stresses for parts subjected to both alternating and steady stresses based on the static yield point and the endurance limit for completely reversed stresses

MANY machine parts are subjected to alternating stresses upon which steady stresses are superimposed, where designers wish to know what maximum stress may be used for indefinite endurance for various ratios of minimum to maximum stress.

When various ratios of minimum to maximum stresses are employed the Goodman diagram, shown in Fig. 1, is often used to represent the behavior of wrought ferrous metals under the action of repeated stresses. The line *EB* represents the ultimate tensile strength, and the minimum stresses for the various cycles are plotted along the 45 deg. line *DOB*. The maximum stresses are assumed to fall along the line *CAB*, in a manner such that *CD* represents the condition of completely reversed stresses. The endurance limit is taken to be 33 per cent of the ultimate tensile strength.

Objections to this diagram are: First, few experiments have been made to verify its correctness, undoubtedly because the experimental verification requires the determination of a series of endurance limits for a variety of ratios of minimum to maximum stress, which is tedious and expensive even when an appropriate machine for the tests is available. Secondly, for wrought ferrous metals the average ratio of endurance limit to ultimate tensile strength is more nearly 50 per cent rather than 33 per cent. A more important objection is that it would probably never be desirable to use a cyclic maximum stress which exceeded the yield point of the material, because such a stress could cause undesirable permanent deformation. Therefore, all that part of the diagram lying between the yield point of the material and the ultimate tensile strength is useless for practical applications.

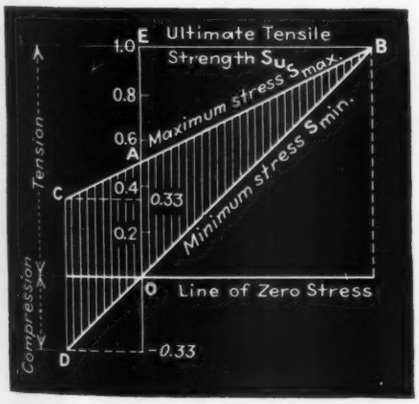


Fig. 1—Goodman range-stress diagram which is sometimes used to show the behavior of wrought ferrous metals under the action of repeated stress

To overcome the first objection to the Goodman diagram, H. F. Moore and the author proposed the following formula for the maximum stress in any cycle:

$$S_{max} = (3S_{-1})/(2-r) \quad \ldots\ldots\ldots\ldots (1)$$

in which S_{max} = the maximum unit stress in lb. per sq. in. in a cycle,

S_{-1} = the endurance limit in lb. per sq. in. for completely reversed stresses,

r = the ratio of minimum to maximum unit stress in a cycle. This may be positive or negative depending on whether the stresses are of the same or opposite sign.

No constant ratio of the endurance limit for completely reversed stresses to the ultimate tensile strength is assumed, but the formula does assume that the endurance limit is 1.5 S_{-1} when the minimum stress is zero, as required by the Goodman diagram. While this formula disposes of one objection to the Goodman diagram, it does not overcome the main objection mentioned in the preceding paragraph. When suggested it was stated that this formula did not justify the consideration of maximum stresses which were high enough to cause static failure, either elastic failure or rupture.

In 1910, J. H. Smith published in the *Journal* of the Iron and Steel Institute, Part II, 1910, p. 246, a paper on a series of tests in which he used diagrams having the average or mean stress in a cycle as abscissas and the maximum and minimum stresses as ordinates. Fig. 2 shows one of these diagrams with the experimental results obtained from endurance tests. Smith employed a machine which permitted him to apply completely reversed alternating stress plus various amounts of mean stress to determine certain "yield ranges." The specimen was subjected to an alternating stress plus a small increment of mean tensile stress, and then the mean stress was changed to the same amount in compression, continuing with increasing increments of mean stress until a slight yielding took place. It was found that the maximum stress for the yield range was not in general the ordinary tension or compression yield stress, and that the same specimen could be used to determine the yield range for various values of mean stress. The yield range diagrams were similar to that shown in Fig. 2 and the important conclusion was drawn that the yield ranges were equal to the Wöhler limiting ranges.

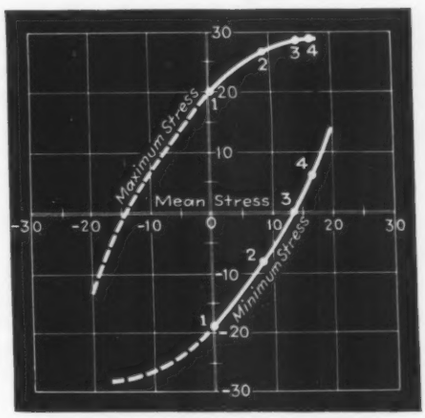


Fig. 2—Limiting range for 3.25 nickel-steel deduced from endurance tests (J. H. Smith). Average or mean stress in a cycle is plotted as abscissa, the maximum and minimum stresses are shown as ordinates

A simplified diagram that requires for its construction only the static yield point and the endurance limit for completely reversed stresses, and that uses straight lines instead of curves, is shown in Fig. 3, from which can be obtained the maximum and minimum stresses which can be withstood indefinitely for any value of mean stress. Also, the maximum stress so obtained will not cause permanent deformation.

In the simplified diagram the mean or

average stress S_{av} is plotted as the abscissas and the alternating stress has the maximum and minimum stresses plotted as ordinates. When the same scale is used for ordinates and abscissas a 45 deg. line, the upper end of which corresponds to the static yield point, can be drawn through the origin of coordinates. Two straight lines are drawn from the static yield point value to the plus and minus values of the endurance limit for completely reversed stresses with mean stress zero.

Instead of the static yield point, the upper limit of stress in the diagram should be the unit stress at which no deformation takes place with time. Since such creep limits are usually not available, the static yield point is considered to be a sufficiently accurate approximation. For steels having an upper and lower yield point, the lower value is chosen. It is to be clearly understood that when the alternating stresses are tension and compression the tensile yield point is used, while for torsional stresses the yield point in torsion is employed.

A comparison of Fig. 2 and 3 will show that Fig. 3 will usually give maximum and minimum stresses on the side of safety, since the stresses found by alternating stress experiments usually lie outside of the straight line limits.

The following notation will be used in discussing this diagram:

S_{max} = maximum unit stress in a cycle
S_{min} = minimum unit stress in a cycle
S_{av} = mean or average unit stress in a cycle
$\pm S_a$ = alternating unit stress in a cycle

Table I—Test Data From Three Different Steels

1	2	3	4	5
Kind of Steel	*Ultimate Tensile Strength lb/sq. in.*	*Yield Point lb/sq. in.*	*Endurance Limit lb/sq. in*	*Endurance Ratio*
0.62% C.....	134,500	64,800	48,800	0.36
0.27% C.....	78,500	52,200	34,000	0.43
0.37% C (Sorbitic).....	102,600	87,300	57,000	0.56

S_y = static yield point stress
S_{-1} = the endurance limit for completely reversed stresses
$r_1 = (S_{av})/(S_y)$ = the ratio of the mean stress in a cycle to the yield point stress.

From Fig. 3 the following equations are evident:

$$S_{max} = S_{av} + S_a \quad \ldots\ldots (2)$$
$$S_{min} = S_{av} - S_a \quad \ldots\ldots (3)$$
$$S_a = S_{-1}(1 - r_1) \quad \ldots\ldots (4)$$
$$S_{av} = (S_{max} + S_{min})/2 \quad \ldots\ldots (5)$$

When making a comparison between the results obtained from Equation (1) and from Fig. 3, it is desirable to have the maximum stress taken from Fig. 3 expressed in terms of r, the ratio of the minimum to the maximum stress in any cycle, which can be expressed as:

$$S_{max} = \frac{2S_{-1}}{(1 - r) + [S_{-1}(1 + r)/S_y]} \quad \ldots (6)$$

It is interesting to compare the maximum stresses obtained from Equations (1) and (6) for three different carbon steels. The yield points in tension and the endurance limits for completely reversed bending stresses shown in Table I were determined by the author. The endurance ratio, shown in Column 5 of Table I, is the ratio of the endurance limit to the ultimate tensile strength, which for wrought ferrous metals is approximately 0.50. The steels were chosen to represent metals in which the endurance ratio is very low, medium, and quite high.

From the data in Table I, the values of S_{max}, shown in Table II, were calculated from Equations (1) and (6), with values of r as listed.

For all three steels Table II shows that as r increases from —1 to 0, S_{max} as given by Equation (1) increases, until at r equal to 0 the value of S_{max} exceeds the yield point for the 0.62 per cent carbon steel, and is almost equal to the yield point for the other two steels. For r between 0.2 and 1, the values of S_{max} as given by Equation (1) all exceed the yield points of the materials. If the maximum stress employed in design is to be such that the possibility of excessive deformation must be avoided in addition to the possibility of failure by fatigue, then any values calculated from Equation (1) which exceed the yield point have no significance for the designer. In contrast to this, the values of S_{max} calculated from Equation (6) are seen to increase gradually for r between —1 and 1, that is, from the endurance limit for completely reversed stresses to the yield point.

When the designer has available the endurance limit for completely reversed stresses and the yield point, Fig. 3 and Equations (2), (3), (4), (5), and (6) provide a simple means for determining endurance limits for various combinations of alternating and mean stress.

Herold, in "*Wechselfestigkeit metallischer Werkstoffe*," 1934, points out that if a specimen is carrying a constant static stress and is then subjected to alternating stresses of increasing amplitude, allowing the alternating stress for each increase of amplitude to act until equilibrium is established, the mean stress at first will remain constant, independent of the value of the alternating stress, as has been shown by Smith. However, beyond a certain alternating amplitude, which is again dependent on the value of the mean stress, the mean stress will decrease. This maximum alternating stress which can just be supported with a given mean stress without

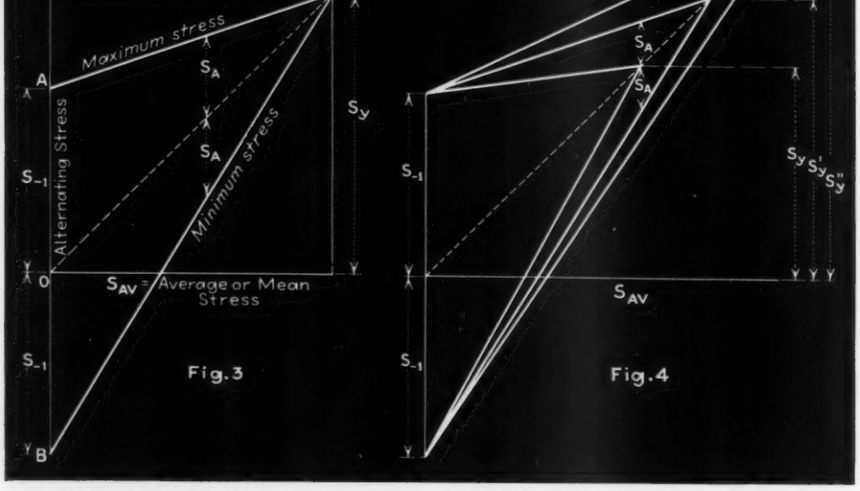


Fig. 3—Simplified diagram for alternating stress plus mean stress using straight instead of curved lines. Fig. 4—Alternating stress diagrams for three different materials to illustrate that it is possible to have several materials with different yield points and in addition all have the same endurance limit for completely reversed stresses

causing the mean stress to decrease, is designated as the alternating yield limit corresponding to this mean stress. It is self-evident that construction elements must not be stressed above the alternating yield limit, therefore, the alternating yield limit is as important in the practical application of materials as is the endurance limit.

Experiments indicate that the alternating yield limit is not influenced by notch effects, and can therefore lie above the endurance limit in certain cases. In constructing a diagram like Fig. 3, therefore, the highest permissible stress should be chosen at which rupture will not occur because of repeated stresses, but under which permanent deformation will also not occur. If the alternating yield limit lies below the endurance limit, then the former is decisive, and vice versa. For polished steels the endurance limit is usually decisive up to that part of the diagram at which the minimum stress of the cycle is zero. Beyond this point the alternating yield limit must be employed.

The author has tested annealed Armco iron and found the endurance limit for completely reversed bending stresses to be 15 per cent higher than the yield point obtained from a static tension test. For such materials it is suggested that the diagram of Fig. 3 be constructed by using the yield point rather than the endurance limit for the case of zero mean stress. This would make the line for S_{max} horizontal when constructing the diagram, but otherwise there would be no change.

A similar phenomenon may be encountered in connection with non-ferrous metals since they have no yield point in the sense that many steels have yield points. In such cases the so-called "yield strength" is determined by finding the unit stress on a stress-deformation curve at which the permanent deformation is 0.1 or 0.2 per cent. If the yield strength so determined is less than the endurance limit for completely reversed stresses, in constructing a diagram like Fig. 3 it is suggested that the yield strength be used at zero mean stress.

In constructing alternating stress diagrams, Herold points out that several materials with different yield points may all have the same endurance limit for completely reversed stresses, Fig. 4 shows three such materials. The diagram shows that when the weakest material is stressed to its yield point the alternating stress would have to be zero. For the other two materials, however, it would still be possible to apply some alternating stress when this same mean stress is used. Thus, materials with high yield points have a distinct advantage not only in withstanding static stresses, but also combinations of alternating stress plus mean stress.

Experimental results of combinations of alternating stress and mean stress for cast irons are meager. Moore, Lyon, and Inglis have reported in the Univ. of Illinois *Bulletin* No. 164, 1927, some results for a cast iron which had an ultimate tensile strength of 31,600 and an ultimate compressive strength of 111,000 lb. per sq. in. For cases of tension and compression in which the tensile stress in the cycle was numerically greater than the compressive stress the authors suggest the use of Equation (1). For cases of tension and compression in which the compressive stress was numerically greater the following formula was suggested which fitted the experimental results quite reasonably.

$$S_{max} = 6\,S_{-1}/(1-5r) \quad \ldots\ldots\ldots\ldots (7)$$

It should be understood clearly that the use of diagrams such as Fig. 3 and of Equation (6) is advocated only when the designer is working with materials for which complete information regarding the various fatigue limits for different ratios of r is not available. It is true that the endurance limit for completely reversed axial stresses is sometimes less than that for completely reversed flexural stresses, but the use of the endurance limit from rotating-beam tests is suggested as it is more generally available.

As a practical application of Fig. 3 and the equations suppose for example: A part is to be subjected to stresses in tension varying from 10,000 to 20,000 lb. per sq. in. and if the material to be used is the 0.27 per cent carbon steel mentioned previously, what will be the factor of safety?

Here S_{-1} is 34,000 lb. per sq. in., S_y is 52,200 lb. per sq. in., and r is 0.5. From Equation (6):

$$S_{max} = \frac{2 \times 34{,}000}{(1 - 0.5) + [34{,}000 \times (1 + 0.5)/52{,}200]} = 46{,}000 \text{ lb. per sq. in.}$$

This value of S_{max} is the unit stress which could be applied indefinitely without failure, and since the actual S_{max} is to be only 20,000 lb. per sq. in., the factor of safety, so far as repeated stresses are concerned, is 46,000 divided by 20,000 or 2.3. The factor of safety with respect to the ultimate strength may be found by considering that the point C in Fig. 3 corresponds to the case of static loading, when r is unity, and the alternating stress is zero. For the steel under discussion the ultimate strength is 1.5 S_y, therefore 1.5 multiplied by 2.3, or 3.45, is the factor of safety with respect to ultimate strength.

Suppose the problem to be slightly different. Suppose the ratio r is to be 0.5 and the factor of safety as based on ultimate strength is to be 4, what value of S_{max} is permissible? When a factor of safety of 4 is applied to the ultimate strength, the point C in Fig. 3 is reduced from 78,500 to a working unit stress of 19,600 lb. per sq. in. This simultaneously reduces the working S_{-1} in the ratio that 19,600 bears to S_y or 52,200, which is 0.375. Therefore, the working or allowable S_{-1} is 34,000 times 0.375, or 12,800 lb. per sq. in., and from Equation (6):

$$\text{Allowable } S_{max} = \frac{2 \times 12{,}800}{(1 - 0.5) + [12{,}800 \times (1 + 0.5)/19{,}600]} = 17{,}300 \text{ lb. per sq. in.}$$

This value can be checked against the previous solution in which 20,000 lb. per sq. in. was found to be the S_{max} with a factor of safety of 3.45. Thus:

Allowable $S_{max} = (3.45 \times 20{,}000)/4 = 17{,}300$ lb. per sq. in.

To illustrate a case in which r is minus, suppose that the minimum stress is compressive at 10,000 lb. per sq. in., and the maximum stress is tensile at 20,000 lb. per sq. in. Determine the factor of safety with respect to the ultimate strength, using the same steel as in the previous examples. In this case, $r = -0.5$, then from Equation (6):

$S_{max} = 37{,}200$ lb. per sq. in.

The factor of safety for repeated stresses is therefore 37,200 divided by 20,000 or 1.86; and since the ultimate tensile strength is 1.5 S_y, 1.86 multiplied by 1.5 or 2.79 is the factor of safety with respect to the ultimate.

Table II—Maximum Unit Stresses for Three Different Steels
For Various Ratios of Minimum to Maximum Stress

Value of r	0.62% C. Steel		0.27% C. Steel		0.37% C. Steel (Sorbitic)	
	From Equation (1)	From Equation (6)	From Equation (1)	From Equation (6)	From Equation (1)	From Equation (6)
−1	48,800	48,800	34,000	34,000	57,000	57,000
−0.8	51,300	49,900	36,400	35,200	61,100	59,100
−0.6	56,300	51,300	39,200	36,500	65,800	61,300
−0.4	61,000	52,700	42,500	38,000	71,300	63,600
−0.2	66,600	54,100	46,300	39,500	77,700	66,400
0	73,200	55,600	51,000	41,100	85,600	69,100
0.2	81,300	57,200	56,700	43,000	95,000	72,300
0.4	91,400	58,800	63,800	45,000	106,800	75,200
0.6	104,500	60,700	73,000	47,200	122,000	79,300
0.8	122,000	62,600	85,000	49,700	142,000	83,300
1.0	146,400	64,800	102,000	52,200	171,000	87,300

DIE-CAST OR STAMPED

Design Advantages and Relative Costs

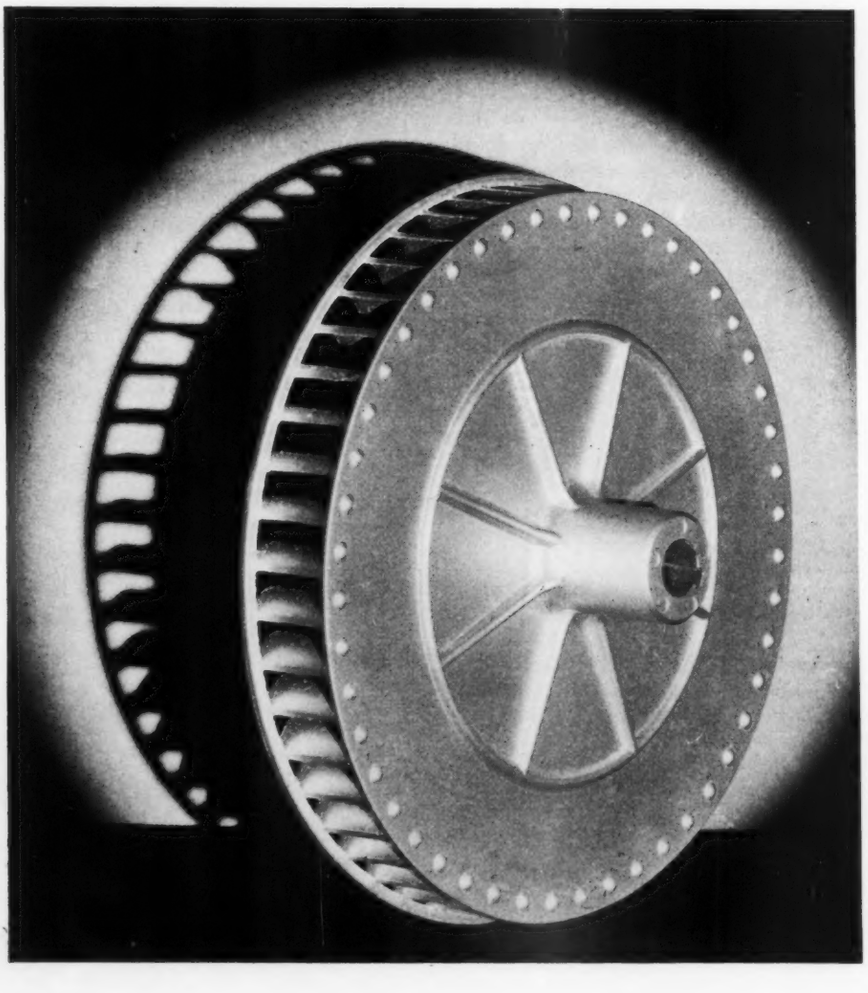
HERBERT CHASE

Part II—Additional discussion of factors that enter into the choice between the use of die-castings or of stampings with more cost data and examples of parts made by both processes

IN THE August number of *Product Engineering* the author set forth the advantages and disadvantages or limitations of die-cast and stamped parts, as he sees them and gave specific examples illustrating many of the points made, together with cost figures drawn from many different sources. Since preparing the first part of the article, the author has visited numerous additional plants in which die-casting and/or stampings are produced or purchased for assembly into a large variety of products and has discussed the relative advantages of both types of parts with numerous engineers and production men. Data on several specific parts produced or figured for production by both methods have been gathered.

In one plant the author was told that more die-castings would be used were it not that the dies required often take longer to make and put into use than do stamping dies, partly because the latter are often assembled from several parts whereas fewer parts or perhaps only two halves are needed in die-casting dies. This condition doubtless applies in some cases, especially where only blanking, piercing and simple bending operations are required, but if drawing dies are required for the stamping, the condition may be reversed.

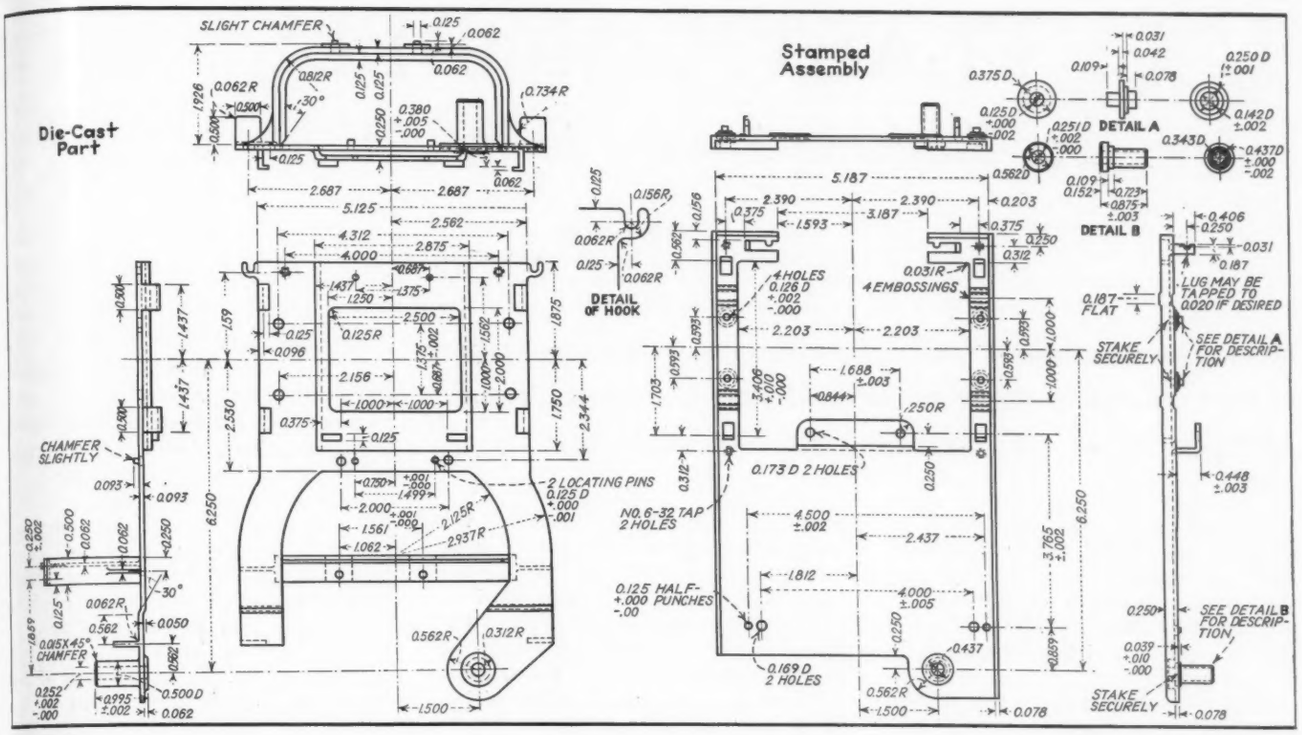
From another manufacturer comes the information that the maintenance on tools, of which a large proportion are for stamping presses, has run over a period of several years between fifty and seventy five per cent of the cost of new tools. Although these figures probably do not apply in many cases to dies producing stampings for which die-castings might be substituted, it is a fact that maintenance charges on stamping dies are often high whereas they are much lower in dies for die casting, especially when the dies are for zinc alloys which cast at a relatively low temperature. In the latter case, maintenance charges are an extremely small factor especially if the dies are well made initially.



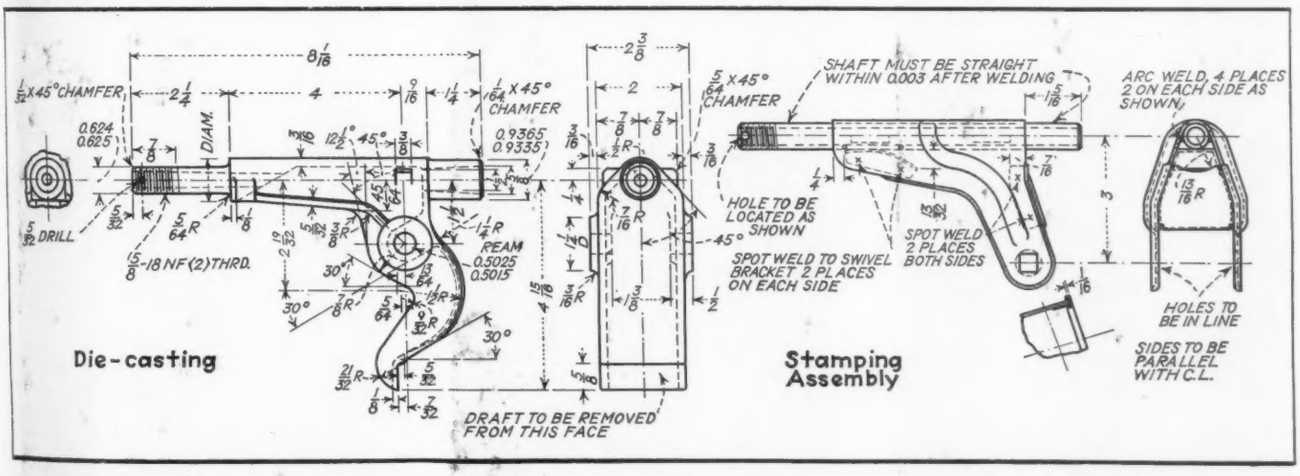
One-piece die-cast rotor for sirrocco-type blower, 8¾ in. diam., has 48 blades 1⅛ in. long, weighs 29½ oz., it displaced a stamped and assembled steel rotor. The die for die-casting cost approximately $750. The finished and balanced die-castings cost the purchaser, who owns the die, about half of what he formerly paid for the finished stamped rotors assembled to a sand-cast hub.

The die-cast rotor is a hub with a flange having integral blades cast on one side. The blades are supported also by an integral ring the inside diameter of which is equal to the diameter at the outside edge of the blades so that the core forming the blade spaces is readily withdrawn. Small nibs are cast on the flange, which are ground off as required in dynamic balancing to within 0.002 in. oz., according to the die-caster. The keyway is formed when die-casting.

In the stamped rotor, the blades are formed separately and have at each end projections which are inserted in holes in a side and a ring plate and are then riveted over to fasten the assembly together. A sand-cast hub is then riveted to the side plate. Data on the cost of the stamping dies are not available, but as these include numerous punches for piercing the holes for blade fastening, as well as a die for blanking the blades and for forming them, it is doubtful if their cost is lower than that for the die-casting die. Assembly operations and machining of the sand-cast hub also increase the cost of the stamped unit.



Support bracket for use in a radio receiver. Was actually produced as a stamping but would have been die cast had it not been possible to secure the stampings in finished form more quickly. The parts are not exact duplicates but perform the same function, the die-casting being made in one piece with integral mounting bosses, whereas the stamping requires the addition of screw-machine parts which have to be staked in place. Only blanking and bending operations are required on the stamped part, no drawing being needed. Appearance is not of special importance, but the stamping, which is of cold-rolled steel, has to be cadmium plated to avoid rusting whereas the die-casting requires no applied finish and is not subject to rusting. Actual quotations on the die for die-casting was $410, and for the castings themselves $139.50 per M in lots of 5,000 and $138 per M for lots of 20,000. The stamping dies cost $695 and the piece price was $107.40 per M. On this basis, the total cost dies included, in lots of 5,000 is $1,232 for the stamping and $1,107.50 for the die-casting. In lots of 20,000, however, the lower piece cost for the stamping brings the total cost, dies included, to $2,743 as against $3,170 for the die-casting. Strength is satisfactory in either form.


Die-casting
Stamping Assembly
SHAFT MUST BE STRAIGHT WITHIN 0.003 AFTER WELDING
ARC WELD, 4 PLACES 2 ON EACH SIDE AS SHOWN
HOLE TO BE LOCATED AS SHOWN
SPOT WELD TO SWIVEL BRACKET, 2 PLACES ON EACH SIDE
SPOT WELD 2 PLACES BOTH SIDES
HOLES TO BE IN LINE
SIDES TO BE PARALLEL WITH C.L.
DRAFT TO BE REMOVED FROM THIS FACE
REAM 0.5025 0.5015

Swivel bracket for outboard marine engine, produced in both die-cast and stamped form. The die-casting was used first and was produced in aluminum alloy to gain light weight and resistance to salt-water corrosion. The part supports the entire weight of the engine and forms the pivot about which the engine is turned in steering. Some breakage occurred in service and this fact, together with the lower piece cost of the stamped assembly resulted in substitution of the latter. In producing the stamped assembly, three sets of dies are required for blanking and forming the two major parts from No. 14-gage (0.078-in.) hot-rolled steel and one from No. 22-gage (0.031-in.) hot-rolled sheet steel, the total cost of the dies and fixtures being approximately $1,075. The pivot is a piece of ⅝-in. seamless steel tubing with No. 14-gage wall. Assembly is effected by arc welding the main stamping to the tubing and spot welding the remaining stampings to the main stamping, after which the assembly is zinc plated, given a dichromate treatment and aluminum painted. The steel assembly is much stronger than the aluminum die-casting. The die for the die-casting cost approximately $1,235. The weights are 10½ oz. for the die-casting and 14½ oz. for the stamped assembly.

ELASTIC MODELS

For Studying Stresses in Welded Joints

E. W. P. SMITH
Consulting Engineer, The Lincoln Electric Company

Method for investigating and comparing stresses in various types of welded joints by observing the deformations produced in scale models made of elastic materials when subjected to loads

STUDIES having for their purpose the utilizing of material in equipment and parts, so that it is distributed to the best advantage, are especially important when welding is used to fabricate the material into an integral homogenous structure.

Some idea of the stress distribution in a loaded joint or part of a machine can be obtained by subjecting an elastic scale model of the joint under investigation to a load and then observing the deformation produced at critical areas.

Any elastic material can be used for the models with good results, provided the test loads applied do not stress the material beyond its elastic range. Rubber, is a convenient material to use because it possesses a low modulus of elasticity, has a fairly uniform structure, is easily obtained and can be readily cut with a sharp knife. The deformation produced in the rubber used is approximately 600,000 times larger than the deformation which would be produced by the same load on a steel specimen of similar shape and size provided, of course, that the materials are not stressed beyond the point where a permanent set results.

The method of making and using the models is as follows; squares or other suitable patterns are layed off on a rubber sheet of uniform thickness, after which the type of joint to be investigated is drawn to scale on the ruled rubber sheet and then cut out. The dimensions of the squares are carefully measured at no load and recorded for the various sections of the model. The model is then subjected to known loads and measurements

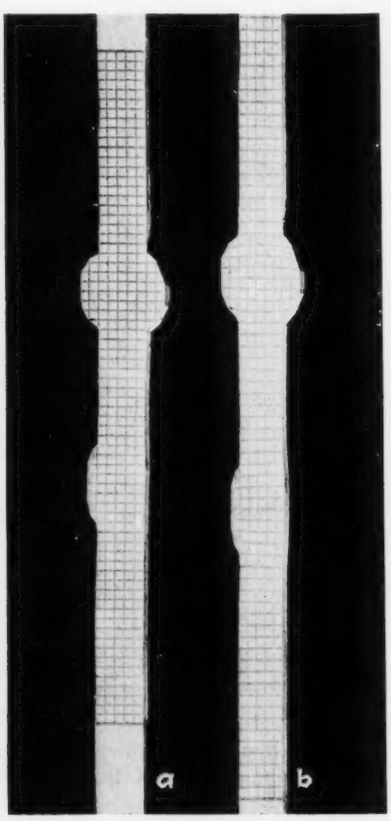


Fig. 1—Single Vee-joint with 20 per cent reinforcement and a heavily reinforced double vee-joint. (a) Before loading. (b) Load applied. Deformations in the heavily reinforced Vee are small at outer edges and large at center. Less reinforcement would improve the stress distribution

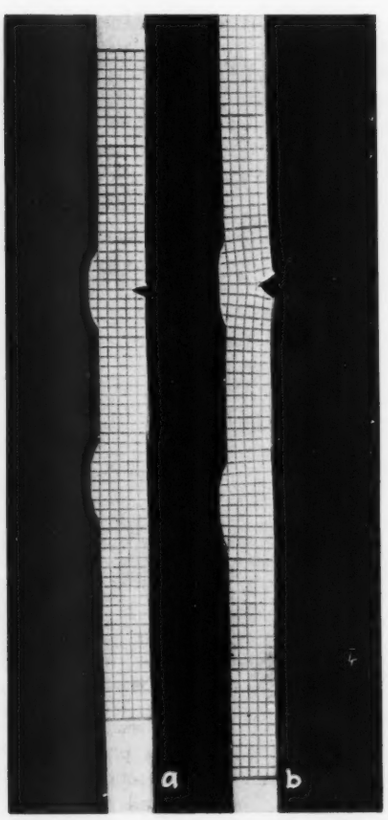


Fig. 2—Single Vee-joint with 20 per cent reinforcement and also same joint with lack of fusion at bottom of Vee. (a) Before loading. (b) Load applied. Failure to fuse bead completely to sides and bottom of Vee result in a notch effect with bending and high stresses

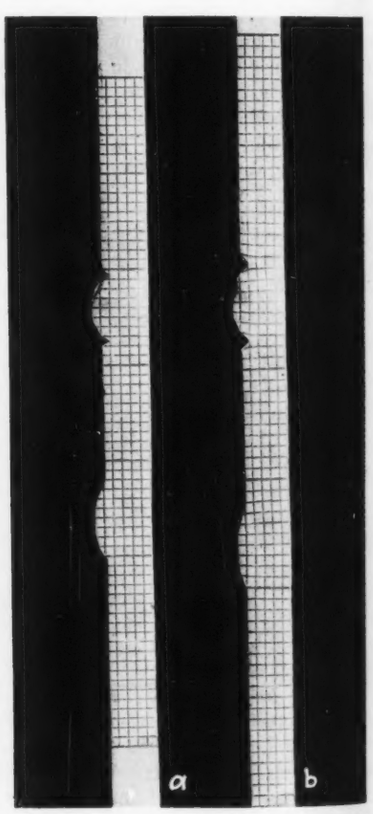


Fig. 3—Single Vee-joints with 20 per cent reinforcements with and without undercutting. (a) Before loading. (b) Load applied. Deformations are not uniform at undercuts which are in effect notches, one on each side of the weld. Joint shown in Fig. 1 has better stress distribution

of the deformed squares are taken under load and recorded.

The linear difference in the dimensions of the separate squares taken at no load and again when loaded is the deformation in the material, and is an indication of the magnitude or amount of stress at the respective particular areas. Knowing by calculation the value of the stress at an area of uniform distribution and by measurement the amount of deformation at that area, the deformation-stress ratio for the material can be easily determined.

Designers who are interested only in the ratio of stress values at various points in the structure, rather than the numerical value of the stresses which are set up under given loads, can quickly arrive at a conclusion by comparing the deformations in originally equal squares since the ratio of the deformations will equal the ratio of the stresses induced. To make a quick comparison of stress distributions in different types of joints the model can be made so as to have the two or more joints under consideration cut out of a continuous sheet of material, and thus subjected to the same load at the same time.

While models made from elastic material can be helpful to the designer for many purposes, such as, the investigation of deflections of parts with non-uniform cross sections and stresses in critical areas of notched pieces, they are particularly useful when it is desired to get a general idea of stress distribution when designing equipment or parts that are built up by welding.

Welding fuses the component parts of machines into one homogenous structure and the strength of the metal in a good weld equals or is better than that of the base metal of which the product or structure is built. Distributing the material in welded structures so that the stresses induced by load conditions are equal at all points results in the maximum efficiency in the use of materials with a consequent reduction in costs. Even though the stress is low in some areas if the uniformity of stress distribution is improved the cost is reduced. It is obvious, however, that if in one part of the structure the stress is high as compared to another part where it is lower that the high stress will be the governing factor.

The design problem should be approached not from the viewpoint of eliminating high stresses at particular points, but rather that of meeting all load conditions at all points thus obtaining maximum efficiency by utilizing the entire section in the best way.

The maximum allowable stress for good weld metal is 32,000 lb. per sq.in. when subjected to fatigue or endurance loads, this value is a load limit just as the ultimate tensile strength is a limit and the yield point is a limit. If, therefore, by design of the part the unit stress is kept below 32,000 lb. per sq.in., and if the stress is uniformly distributed, the section will be economical in the use of material.

As examples of how elastic models can be effectively used in studying stress distribution and for investigating stress ratios in tentative designs, the illustrations show models or specimens cut from rubber sheets which have been previously marked with square patterns. Each model here illustrated was made to represent two different types of weld joints so that they could be compared directly while both were under the same load. A study of the accompanying illustrations will indicate to the designer or engineer how costs may be reduced by using every section of metal to obtain the greatest degree of efficiency.

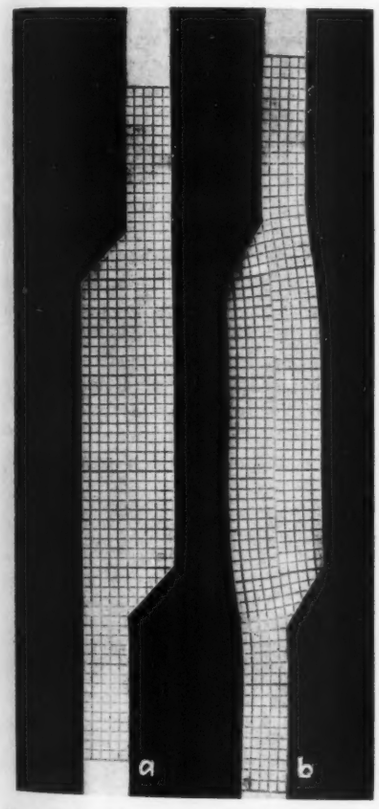


Fig. 4—Double Vee-weld with lack of fusion in center of butt joint and a single Vee-joint. (a) Before loading. (b) Load applied. Deformations at the center or the point of no fusion in the double Vee-weld are greater than those at the outer edge which are only slightly stressed

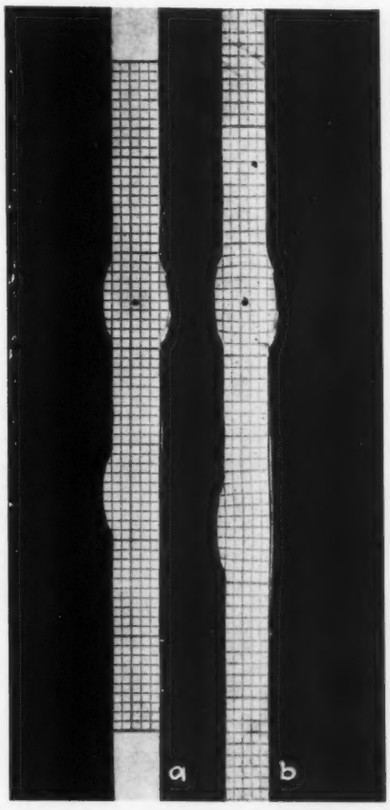


Fig. 5—Lap joint model of weld using two beads. Cost of making this type of joint is usually higher than that for making a butt joint. (a) Before loading. (b) Load applied. There is considerable bending but a study of the deformations indicate that the stress distribution is good

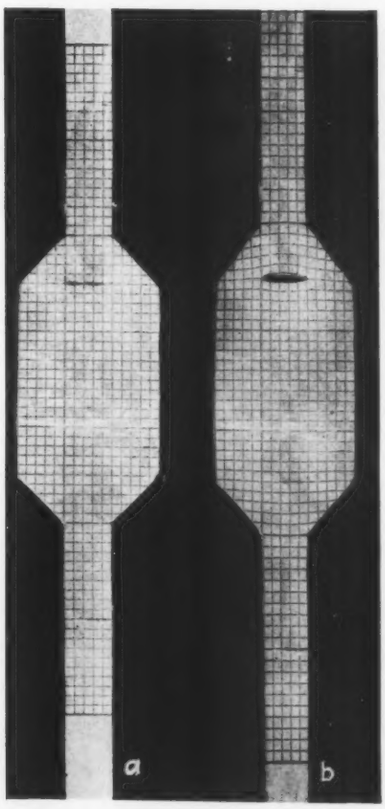


Fig. 6—Plate or bar attached to a member by two different types of connections, fillet-welds and complete fusion. (a) Before loading. (b) Load applied transversely to weld. Deformations are uniform in complete fusion. At fillet-welds the break in stress lines causes disturbance.

TYPICAL VARIABLE-SPEED TR

Ratchet and inertia type mechanisms for variable-speed driving of heavy or light loads

CYRIL DONALDSON
Rochester Athenæum & Mechanics Institute

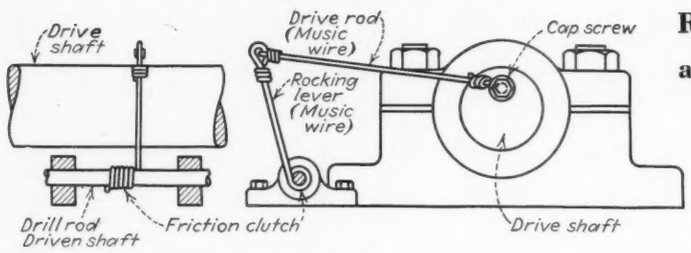


FIG. 30

FIG. 30—A handy variable speed device suitable only for very light drives in laboratory or experimental work. Drive rod receives motion from drive shaft and rocks lever. Friction clutch made by winding wire around drill-rod in lathe with diameter slightly smaller than diameter of driven shaft. Speed ratio changed when unit is stationary, by varying length of rods, or throw of eccentric.

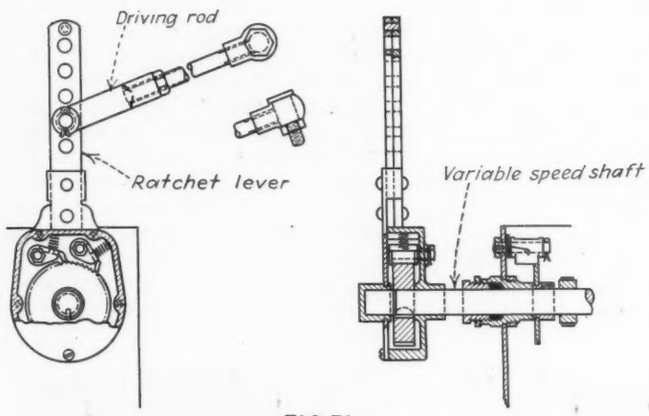


FIG. 31

FIG. 31—This Torrington lubricator drive illustrates the general principles of ratchet transmission devices. Reciprocating motion from a convenient sliding part, or from an eccentric, rocks the ratchet lever, which gives the variable speed shaft an intermittent uni-directional motion. Speed ratio can be changed only when unit is stationary. Placing fork of driving rod in different hole varies the throw of the ratchet lever.

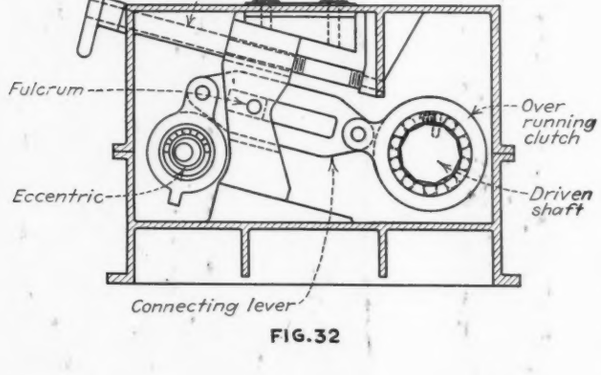


FIG. 32

FIG. 32—An extension of the principle illustrated by Fig. 31, this Lenney transmission replaces the ratchet with an over-running clutch. Speed of the driven shaft can be varied while the unit is in motion by changing the position of the connecting lever fulcrum.

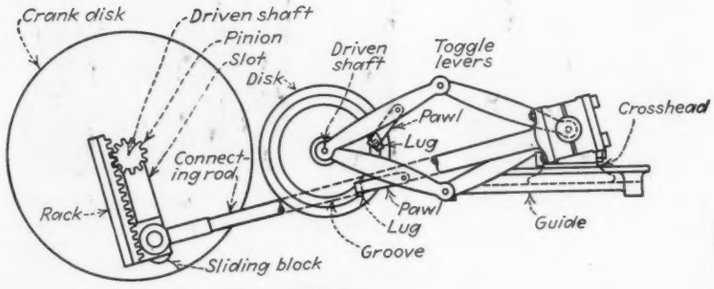


FIG. 33

FIG. 33—Another transmission employing the principle shown in Fig. 31. Crank disk imparts motion to connecting rod. Crosshead moves toggle levers which in turn give uni-directional motion to clutch wheel by means of friction pawls engaging in groove. Speed ratio changed by varying throw of crank with the aid of the rack and pinion.

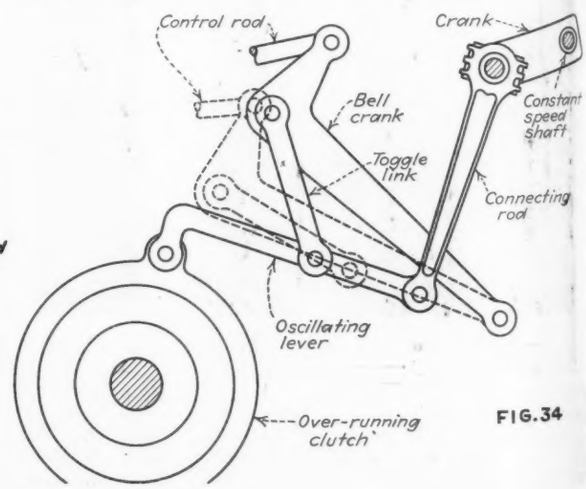


FIG. 34

FIG. 34—A variable-speed transmission used on gasoline railroad section cars. The connecting rod from the crank, mounted on the constant speed shaft, rocks the oscillating lever and actuates the over-running clutch, thus giving intermittent but uni-directional motion to the variable speed shaft. The toggle link keeps the oscillating lever within a prescribed path. Speed ratio changed by swinging bell crank towards position shown in dotted lines, around pivot attached to frame. This varies the movement of the over-running clutch. Several units out of phase with each other are necessary for continuous motion of the shaft.

TRANSMISSIONS—IV

FIG. 35—This Thomas transmission is an integral part of an automobile engine in which piston motion is transferred by means of the conventional connecting rod to long arm of a bell-crank lever oscillating about a fixed fulcrum. Attached to the short arm of the bell crank lever is a horizontal connecting rod which in turn rotates the crankshaft. Crankshaft motion is rendered continuous and steady by means of a flywheel, but no power other than that required to operate auxiliaries is taken from this shaft. The main power output is transferred from the bell-crank lever to the over-running clutch by means of a third connecting rod. Speed ratio is changed by sliding the top end of the third connecting rod within the bell-crank lever by means of a cross-head and guide mechanism. Highest ratio is obtained when the crosshead is farthest from the fulcrum and movement of the cross-head toward the fulcrum reduces the ratio until a "neutral" position is reached when the center line of the connecting rod coincides with the fulcrum.

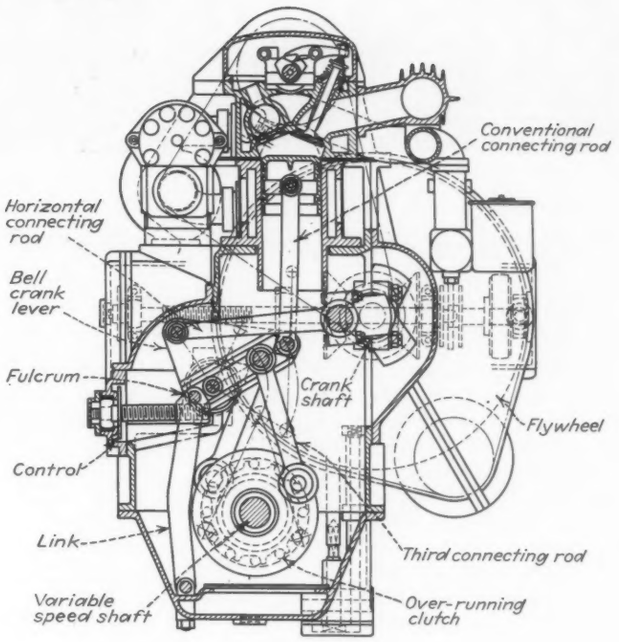


FIG. 35

FIG. 36—Another automobile transmission system built as an integral part of the engine, this Constantinesco torque converter features an inherently automatic change of speed ratio according to the speed and load on the engine. The constant speed shaft rotates a crank which in turn operates two oscillating levers having inertia weights at one end, while the other ends are attached by links to the rocking levers. Incorporated in these rocker levers are over-running clutches. Since at low engine speeds the inertia weights oscillate through a wide angle at low speed, the reaction of the inertia force on the other end of the lever is very slight, and the link imparts no motion to the rocker lever. Speed increase of engine causes inertia weight reaction to increase thereby rocking small end of oscillating lever as the crank rotates. Consequent motion rocks rocking lever by means of link and the variable shaft is driven in one direction.

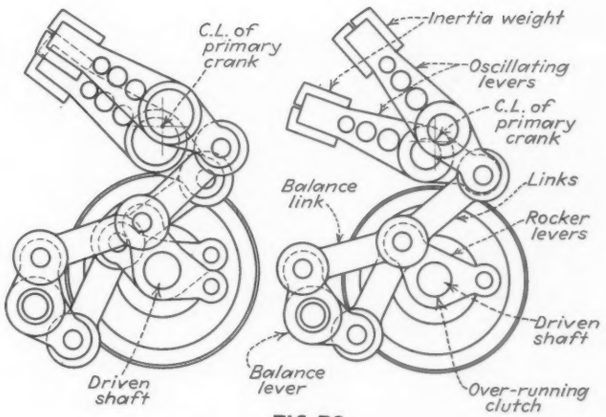
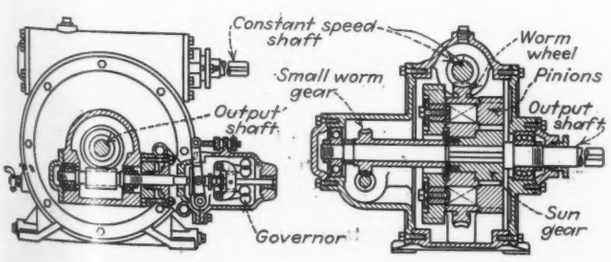


FIG. 36

FIG. 37—Featuring a differential gear with an adjustable escapement, this transmission by-passes a variable proportion of the drive shaft revolutions. Constant speed shaft rotates freely mounted worm wheel carrying two pinion shafts. The firmly fixed pinions on these shafts in turn rotate the sun gear which meshes with other planetary gears, rotating the small worm gear attached to the variable speed output shaft.

FIG. 38—In this Morse transmission, an eccentric cam, integral with the constant speed input shaft, rocks three ratchet clutches by means of a series of linkage systems containing three rollers running in a circular groove cut in the cam face. Uni-directional motion is conveyed to the output shaft from the clutches by planetary gearing. Speed ratio is changed by rotating anchor ring containing fulcrum of links, thus varying the stroke of the levers.

FIG. 37



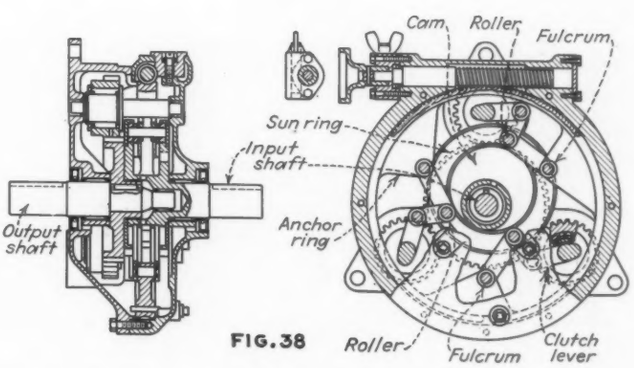


FIG. 38

Question and Comment

Deflection of Trapezoidal-Shaped Cantilever

ALEXIS THOMPSON

The case of a beam rectangular in section and uniformly tapering toward one end with a concentrated load at the narrow end often occurs in the design of flat springs. A beam tapering to a sharp point is, of course, a beam of uniform strength and will give the greatest deflection, but because of the necessary shear allowance and the inconvenience of applying load at a point, the triangular shape is generally found impractical and the trapezoidal shape must be substituted.

If the wide end of the beam has a width a the width of the narrow end can be expressed as na where n can have any value from 0 to 1.

Using the notation of the accompanying graph,

$$\frac{m}{x} = \frac{\frac{a}{2} - \frac{na}{2}}{l}; \quad w = na + 2m =$$

$$na + \frac{1-n}{l} a x$$

To obtain the deflection of this beam, double integration can be used if we express both the bending moment and the variable moment of inertia of section as functions of x.

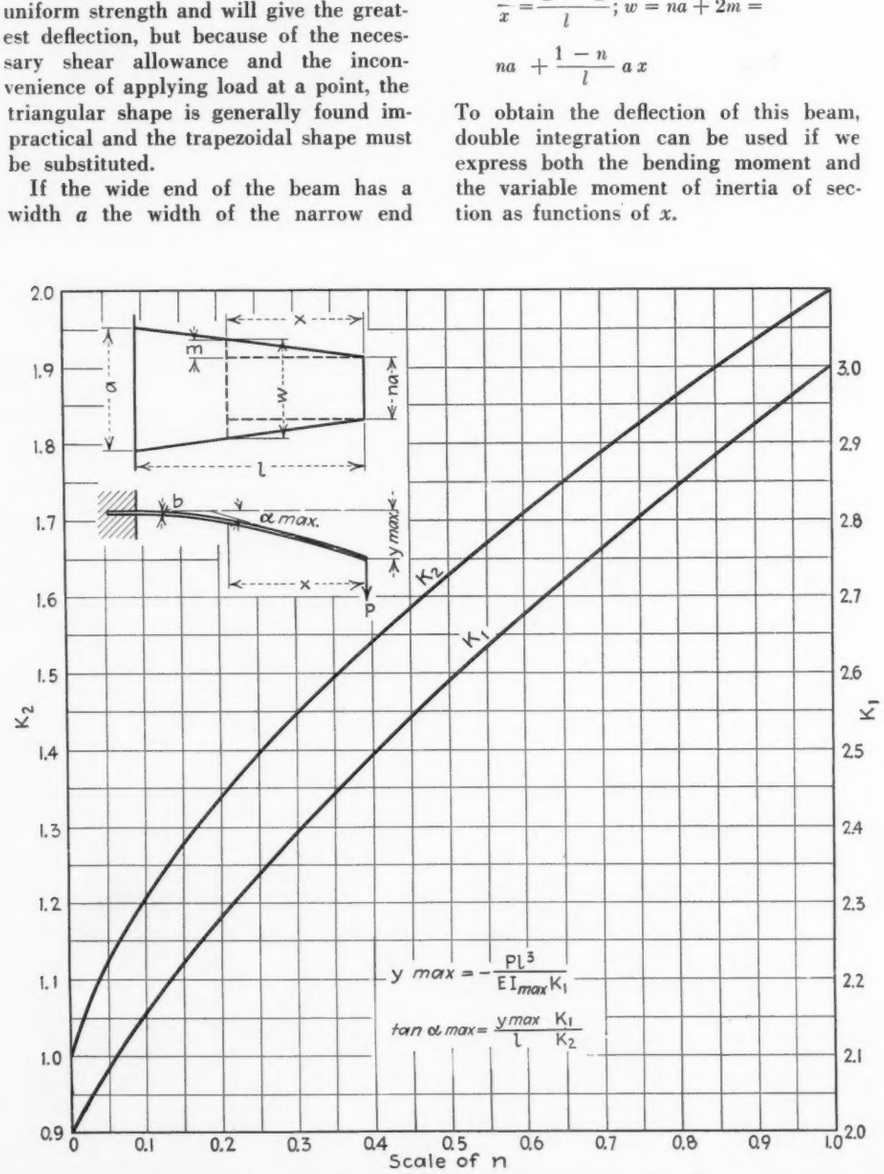


Chart for values of K_1 and K_2 for n varying from zero to one. For a triangular shaped cantilever, n equals zero; for a rectangular shape n equals one

Moment of inertia

$$I = \frac{b^3 w}{12} = \frac{a b^3}{12} (n + \frac{1-n}{l} x) =$$

$$I_{max} \ (n + \frac{1-n}{l} x)$$

$$\frac{d^2y}{dx^2} = -\frac{Pc}{EI} = -\frac{P}{EI_{max}} \frac{x}{n + \frac{1-n}{l} x}$$

Integrating once:

$$\frac{dy}{dx} = -\frac{P}{EI_{max}} \times \frac{l^2}{(1-n)^2} \times \left[\frac{1-n}{l} x + n - n \log_e \left(\frac{1-n}{l} x + n\right)\right] + C_1$$

When $x = l$, $\frac{dy}{dx} = 0$ and $C_1 = \frac{P}{EI_{max}} \frac{l^2}{(1-n)^2}$

Substituting and noting that when

$$x = 0 \ \frac{dy}{dx} = \tan \alpha_{max}$$

$$\tan \alpha_{max} = -\frac{P l^2}{EI_{max}} \times \frac{n(1-\log_e n)-1}{(1-n)^2}$$

$$= -\frac{P l^2}{EI_{max} K_2}$$

Where $K_2 = \frac{(1-n)^2}{n(1-\log_e n)-1}$

Integrating once more:

$$y = -\frac{P l^2}{EI_{max} (1-n)^2} \left[\frac{1-n}{2l} x^2 - (1-n) x - n \frac{\frac{1-n}{l} x + n}{\frac{1-n}{l}} \log_e \left(\frac{1-n}{l} x + n\right) - n \frac{\frac{1-n}{l} x + n}{\frac{1-n}{l}}\right] + C_2$$

When $x = l$ $y = 0$ and $C_2 = \frac{P l^2}{EI_{max}} \times \frac{(-n^2 + 4n - 1)}{2(1-n)^3}$

When $x = 0$ $y = y_{max}$

$$y_{max} = -\frac{P l^3}{EI_{max}}$$

$$\times \frac{n(1.5 - \log_e n) - 2n + 0.5}{(1-n)^3} = -\frac{P l^3}{EI_{max} K_1}$$

Where $K_1 = \frac{(1-n)^3}{n^2(1.5 - \log_e n) - 2n + 0.5}$

To find what the angle α_{max} will be for a certain deflection, we can divide $\tan \alpha_{max}$ by y_{max}

$$\tan \alpha_{max} = \frac{y_{max}}{l} \frac{K_1}{K_2}$$

For example, consider a flat steel cantilever, 0.20 in. thick, 12 in. long, 3 in. wide at point of support and ½ in. wide at end where a load of 40 lb. is applied.

$E = 30{,}000{,}000$

$n = 1/2 \div 3 = 1/6 = 0.167$

$I_{max} = \frac{1}{12} \times 3 \times (0.20)^3 = 0.002$

$K_1 = 2.24 \qquad K_2 = 1.29$

$$y_{max} = -\frac{40 \times 1{,}728}{30{,}000{,}000 \times 0.002 \times 2.24} = 0.51 \text{ in.}$$

$$\tan \alpha_{max} = \frac{0.51 \times 2.24}{12 \times 1.29} = 0.0738$$

Geneva Motion Gearing

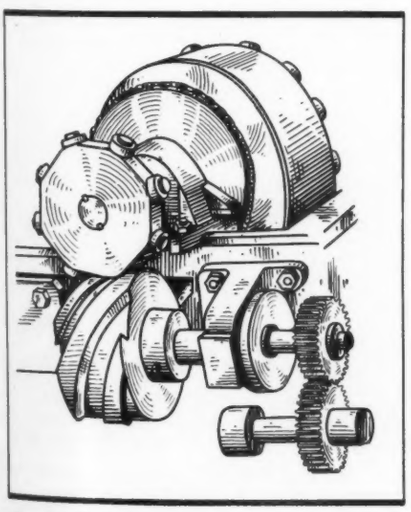
To the Editor:

In June 1938 *Product Engineering*, Mr. C. C. Webb of Wheeling Stamping Company asked for information about Geneva motion gearing. He mentions that the drive must move an unusually large mass, so evidently the inertia load is an important factor. Note on the accompanying diagram of acceleration for Geneva drive, which permits calculation of the torque created by inertia forces, that the inertia load is high at the start and end of each movement, so at high speed the instantaneous application of the inertia force may cause unfavorable vibrations of the machine.

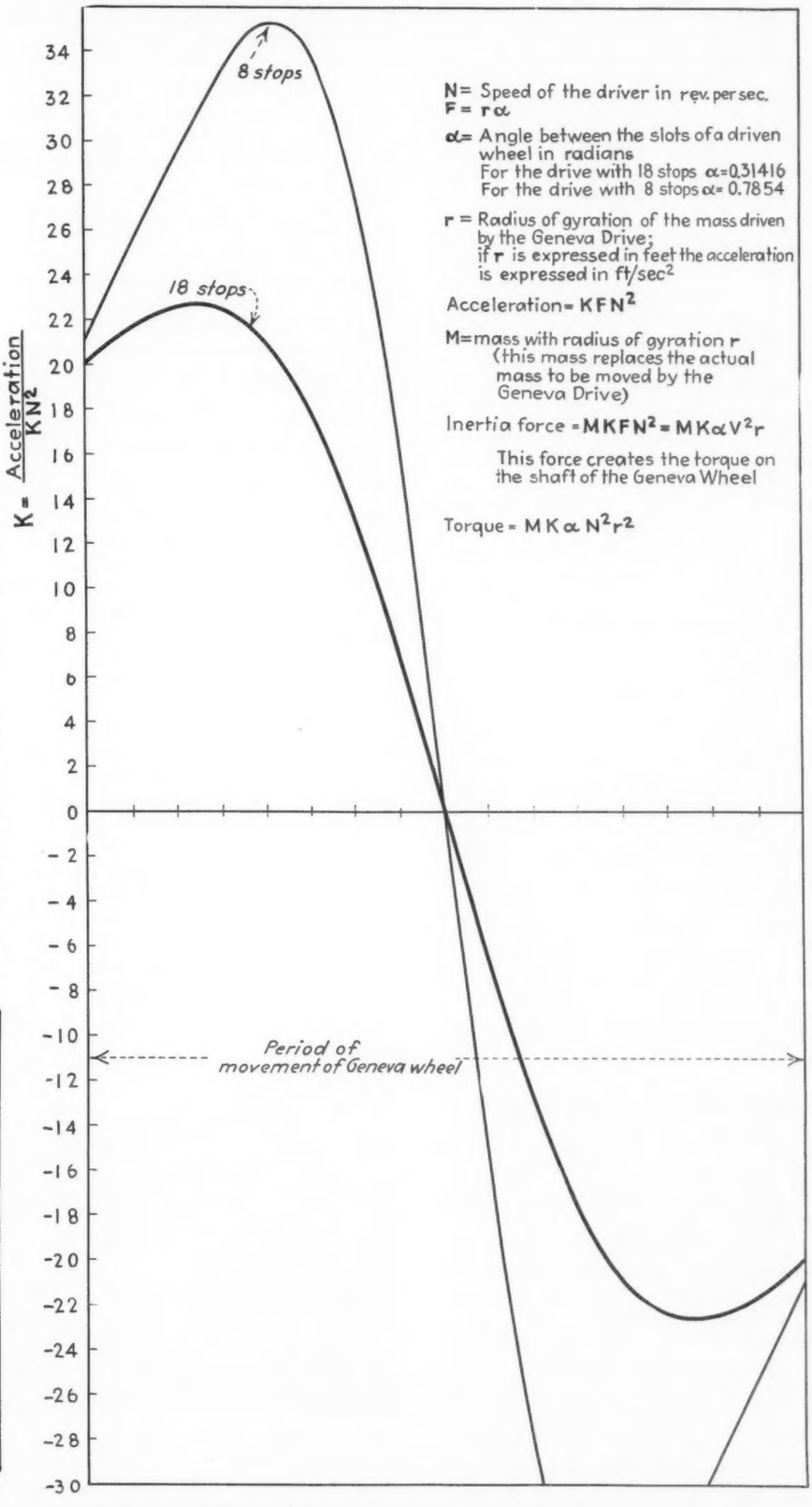
At our plant we avoid using Geneva drives because of this and also because lack of precision in locking the driven wheel during the stop period. Besides the working period of the Geneva drive is often shorter than can be used on the machine; for instance, the Geneva wheel with 8 slots moves while the driver turns on 135 deg., the wheel with 18 slots moves during 160 deg., and in some instances we are able to use movements which have a working period of 240 deg. (on the driving shaft). The acceleration is inversely proportional to the square of the working period.

We advocate the use of the mechanism shown on the accompanying drawing—it guarantees a precise locking. It can be built by Alpha Machine Tool Company of St. Louis. The movement has a very favorable acceleration diagram with low maximum acceleration and without abrupt variation. —C. NEKLUTIN

Universal Match Corporation



Cam and roller gear with eight rollers making four stops per revolution



Acceleration diagram for Geneva drives with eight and eighteen stops per revolution

Drafting Problem

To the Editor:

The "Drafting Problem" on page 268, July 1938, is an interesting one, but the mathematical solution is not so difficult as the drafting board layout.

From the accompanying figure:

$\frac{5-y}{11-x} = \frac{x}{y}$, or $5y - y^2 = 11x - x^2$

and $x^2 - y^2 = 11x - 5y$ (1)

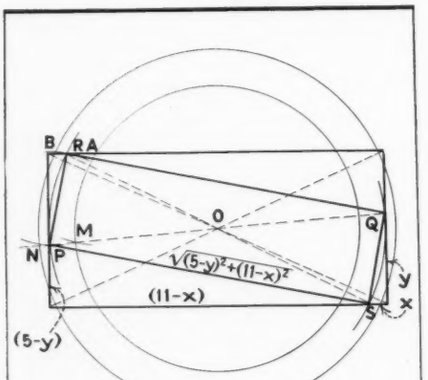
also $x^2 + y^2 = 9$ (2)

By adding (1) and (2) $2x^2 = 11x - 5y + 9$

from which $y = \frac{11x - 2x^2 + 9}{5}$

Substituting in (2) $2x^4 - 22x^3 + 55x^2 + 99x - 72 = 0$

The easiest way to solve this equation is probably the "cut and try" method. By graphical inspection, the value of x appears to be between ½ in. and ⅝ in. By substituting 0.5 for x, the summation of positive terms is 63.375, and negative 74.75. Trying $x = 0.6$, the summations are +79.459, and −76.752. The true value therefore lies between 0.5 and 0.6, but closer to 0.6. After two or three more trial summations, it will be found that $x = 0.581$, gives totals of +76.312 and −76.314, — close enough for all practical purposes. With this value for x, $y = 2.943$ in., $11 - x = 10.419$ in. and $5 - y = 2.057$ in. These last two figures are the legs of the right triangle, the hypotenuse, 10.62 in., is the length of the small rectangle.



Graphical method for approximate solution of July's drafting problem

As a construction problem, the following method should give the desired degree of accuracy. Draw the diagonals of the given rectangle, intersecting at O. With O as a center, draw two circles, one a little smaller and one a little larger than the circle which would circumscribe the required rectangle. Let these circles intersect the given rectangle at A and B respectively. With these two points as centers and a radius of 3 in., describe arcs cutting the two circumferences at M and N respectively. The line connecting these two points cuts the end of the given rectangle at P.

With P as a center and a radius of 3 in., cut the long side of the given rectangle at R. Check by using O as a center and OP as a radius. The other corners can be located by drawing the lines RO and PO, extending them to meet the other side and end of the given rectangle at S and Q respectively. Location of S can be checked by using RO as a radius, and O as a center, while the location of Q may be checked by using S as a center and a 3 in. radius.

The two rectangles will be concentric at O, and the vertices P and R will lie on the end and side of the given rectangle where they are cut by a circle with O as a center and a radius which makes the chord $PR = 3$ in. in length.

The approximate location of R can be determined very closely, as lying near the vertex of the given rectangle. Any number of circles can be drawn, using O as a center so as to establish several approximate locations of R. With these points as centers and a radius of 3 in., a series of points similar to M and N may be established. The line joining these points is curved so slightly where it intersects the end of the given rectangle, that it may be considered a straight line, especially if M and N are not too far apart.

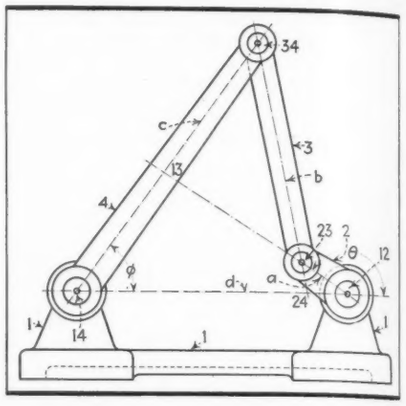
—H. G. TAYLOR
Indianapolis, Ind.

[Editor's Note—Since publication of the September number of *Product Engineering*, we have received additional solutions to the teaser offered by Mr. Hinman in July from Olav Helleland, *Geneva, N. Y.;* Henry Venable, *Pittsburgh, Pa.;* J. A. Bradshaw, *Putnam, Conn.;* Raymond G. Wetzel, *San Bruno, Cal.;* D. Bruce Johnston, *Coatesville, Pa.;* William W. Johnson, *Cleveland, Ohio;* Rolla D. Pollack, *Rock Island, Ill.;* D. A. Cotton, *Anderson, Indiana;* Norman W. Wickstrand, *Bristol, Conn.*]

Four Link Motion

To the Editor:

Under "Question and Comment" in the December issue of *Product Engineering* Mr. Rasche asks four questions about the widely used four link motion.



(Question No. 1) If a, b, c, d are the lengths of the four links

$$m = \sqrt{d^2 + 2ad\cos\theta + a^2}$$

$$\phi = \tan^{-1}\frac{a\sin\theta}{d + a\cos\theta}$$

$$+ 2\sin^{-1}\frac{1}{2}\sqrt{\left(\frac{b-m}{c} - 1\right)\left(\frac{b+c}{m} - 1\right)}$$

Note that for imaginary values $\sin^{-1} i = 90°$ and care should be taken for the proper sign of sin and cos θ.

The second question, the angular velocity ratio of links c and a is answered by the following formula.

N_c, N_a = angular velocity of links c and a

$$\frac{N_c}{N_a} = \frac{d/c - \cos\phi + \sin\phi\cot\theta}{\left(\frac{d\sin\phi}{a\sin\theta}\right) - \cos\phi + \sin\phi\cot\theta}$$

$$= \frac{d/c\tan\theta - \cos\phi\tan\theta + \sin\phi}{\left(\frac{d}{a}\frac{\sin\phi}{\cos\theta}\right) - \cos\phi\tan\theta + \sin\phi}$$

—JEROME CALCAGNETH
Easton, Pa.

Can You Work This One?

H. E. SMITH
Newark, N. J.

Solution to Last Month's Problem:

Storekeeper and Weights

In order to weigh out, on balance scales, any exact multiple of one pound, up to and including 121 lb., any weight must equal twice the sum of all the smaller weights, plus one pound. Calling the smallest weight a, the weights will be $2a + 1$, $6a + 3$, $18a + 9$, $54a + 27$. Weights are 1, 3, 9, 27, 81 lb.

This Month's Problem:

Flagpole, Rope and Stone

Two flagpoles, 110 and 130 feet tall respectively, stand on a level plane. On the line joining their bases is a stone. A rope long enough to reach from the top of one pole to the top of the other will also reach from the top of either pole to the stone. How long is the rope that satisfies these conditions?

News

Research Laboratory Includes Miniature Steel Plant

IN THE NEW research and development laboratory of the Jones & Laughlin Steel Corporation, Pittsburgh, steel-making facilities such as an open hearth furnaces, heat treating furnaces and rolling mills of pilot plant size are used in conjunction with chemical, physical and metallographical laboratories in a direct approach to solving the problems of steel quality.

In the past, research by laboratory procedure generally resulted in advancements being made in research faster than they could be tested and applied in the mills. The J & L research and development department overcomes this handicap by adding to the research laboratory a pilot plant in which steel making practices on a small scale resembling mill conditions can be studied. Thus when new or improved practices are turned over to the mills, they can be certified to be commercially practicable. In addition, the staff is working to develop new furnace designs for bettering the quality of steel.

The research and development division is under the direction of H. W. Graham, general metallurgist, so that the attention of the research staff headed by H. K. Work, manager, will be directed toward current problems and coordinated with the metallurgical departments in the mills. This general supervision also concentrates the research and development activities, yet separates them from the routine metallurgical control work carried on in the Pittsburgh and Aliquippa plants.

The type of equipment installed in the new laboratory has been selected with primary attention to steel-making. A feature of this equipment is the small open hearth furnace, designed by the research staff, which has a capacity of 1,500 lb. and parallels conditions in the big steel furnaces in the works. This furnace, a recuperative and not a regenerative type, is equipped with an unusual type burner. Ingots cast from this furnace weigh from 185 to 900 lb. as compared with ingots from commercial production which weigh from 3½ to 10 tons. The laboratory ingots are rolled in the pilot plant; in some special investigations they are rolled in the regular mills.

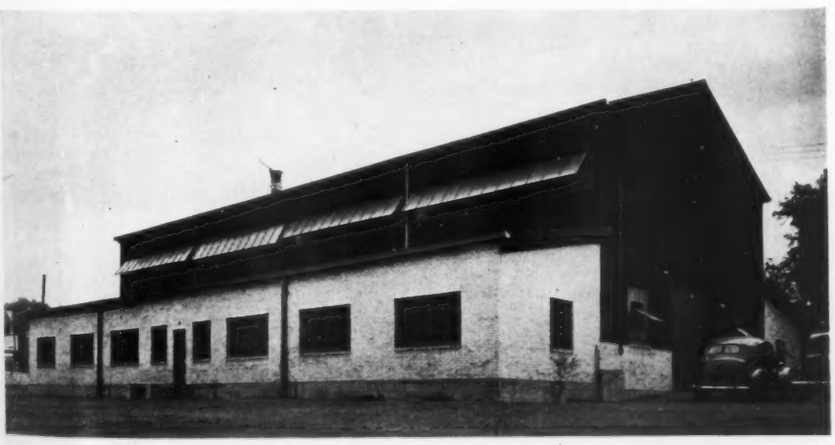
In addition to the open hearth furnace, steel making facilities include a 375 lb. electric-arc furnace used for experiments on slag and steel making and a 30 lb. electric induction furnace which affords exacting control over experimental steel making. A cupola is available to supply molten iron for a small Bessemer converter which will be constructed later. Both metal and slag analyses determinations of steel produced in the pilot plant are made in the chemical laboratory nearby.

Two rolling mills are used in the laboratory, for reduction of the bars into convenient test sizes. The larger mill is capable of reducing a four-inch ingot to a one-inch square; the smaller mill, which simulates conditions in a billet mill, will reduce a 1¼ in. square to ½ in. square. A surface combustion furnace for billet heating, a heat treating furnace, a small soaking pit, a 500 lb. steam hammer and a welding machine complete the equipment.

The physical laboratory is equipped with tensile, impact and hardness testing machines, fatigue and repeated impact testing machines, a stiffness tester for sheet and strip, a dilatometer, and other special equipment. A damping capacity tester for studies on aging and the sensitivity of steels to cold work, one of the first to be used in this country, measures the internal friction of metal by the method of free vibrations.

The metallographic laboratory equipment includes a Zeiss microscope equipped with camera with which micro-photographs of the grain structure of steel may be taken at magnifications up to 4,000 diameters. Other photographic equipment, including a motion picture camera and a complete photographic dark room, is also available.

The work at the pilot plant is being directed toward improving and controlling the physical properties of carbon steels. In this connection, work is being carried on in the field of non-aging steels. Investigations of machinability are being continued by the research department, and studies of the problem of sensitivity or the degree of change of physical properties resulting from cold working of steels will be continued with the aid of the improved facilities in the new laboratory.



New research and development laboratory at the Pittsburgh Works of the Jones & Laughlin Steel Corporation. The pilot plant is flanked by offices and laboratories. Provision has been made for future expansion. Electric power, compressed air, steam, and other services are supplied from the mills nearby

National Metal Congress Opens October 17

THE National Metal Exposition and Congress will be held the week of October 17 to 21 at Convention Hall, Detroit. An attendance of 10,000 is expected and more than 230 leading companies have taken space as exhibitors.

Two educational courses will be among the features of the program. One course, beginning at 4:30 each afternoon, will cover machinability of steels and non-ferrous metals, while the other, to be delivered at 8 p.m. on Monday, Tuesday and Wednesday, will be on pyrometry.

Among the papers to be presented at

the technical session will be: "Absolute Hardness," by E. G. Mahin and G. J. Foss, Jr., University of Notre Dame; "The Effects of Fibre on the Notch Toughness of Mild Steel as Influenced by Cooling Rate," by O. W. Ellis, Ontario Research Foundation, Toronto, and J. E. McDonell, Queen's University, Kingston, Canada; "Effects of Special Alloy Additions to Stainless Steels," by Russell Franks, Union Carbide & Carbon Research Laboratories; "Transverse Hardness Tests of Heat-Treated Steels," by G. T. Williams, Cleveland Tractor Company; and "A Metallographic Approach to the Study of the Sensitivity of Steel to Cold Work," by H. K. Work and S. L. Case, Jones & Laughlin Steel Corporation.

Third Annual Porcelain Enamel Institute Forum

THE Third Annual Porcelain Enamel Institute Forum will be held at the University of Illinois, Urbana, Ill., on October 12, 13 and 14.

Among the papers to be presented will be: "Chipping Resistance of Enamels," by Paul L. Smith, Research Fellow, Porcelain Enamel Institute; "Tentative Tests for Abrasion Resistance," by W. N. Harrison, National Bureau of Standards, "Relationship of Some Welding Practices with Certain Enamel Defects," by J. J. Canfield and Alva Taylor, American Rolling Mill Company.

Plastics as Structural Material for Aircraft

UTILIZING plastics in its construction, a new plane, built by the Clark Aircraft Corporation, has a fuselage molded in two parts of thin veneers of wood impregnated with phenolic resin and cemented together with resin. Other airplane manufacturers in this country and abroad are known to be experimenting with the molding of large aircraft members in one piece. This development is discussed at length by Gordon M. Kline, of the National Bureau of Standards, in an article in *Modern Plastics* magazine. Mr. Kline points out that the National Bureau of Standards, with the financial assistance of the National Advisory Committee for Aeronautics, is initiating an experimental investigation of the materials and processes involved in molding airplane structures.

Types of reinforcing materials have been investigated with particular reference to their employment in plastics for aircraft construction. Noteworthy progress has already been accomplished by Kraemer in the German Aeronautical Institute, by de Bruyne and his associates in the laboratory of Aero Research, Limited, and by de Havilland, King and Walker of the de Havilland Aircraft Company, Limited.

Fifth Annual National Motor Truck Show

COINCIDING with the annual passenger car exhibition at Grand Central Palace, the Fifth Annual National Motor Truck Show which will be held this year in the New York Port of Authority Building from November 11 to 17 is expected to exceed previous records for attendance, interest and scope of new models in trucks and in maintenance and operating equipment.

On display will be new tractor-type trucks and heavy-duty trailers, small, streamlined package delivery jobs, and an exhibit of diesel engines by the leading manufacturers of this equipment, such as Cummins, Hercules, Waukesha and the general accessory manufacturers who supply diesel equipment. Esso Marketers will have at their booth complete details regarding the latest developments on fuels for this special equipment.

Huge Press Bends Plates 8-In. Thick

A 6,000-TON capacity bending press for bending plates up to 40 ft. in length and 8 in. in thickness into semicircular shapes for high pressure steel drums, has recently been built by the Baldwin-Southwark Corporation, for installation at the Chattanooga plant of the Combustion Engineering Company.

The bending press consists of two specially-designed vertical presses of 3,000 tons capacity each, connected by bending beams 52 ft. long constructed of plate steel 15 ft. deep and 20 in. thick. The bottom beam, below the foundation line, rests on the cast steel bottom platen.

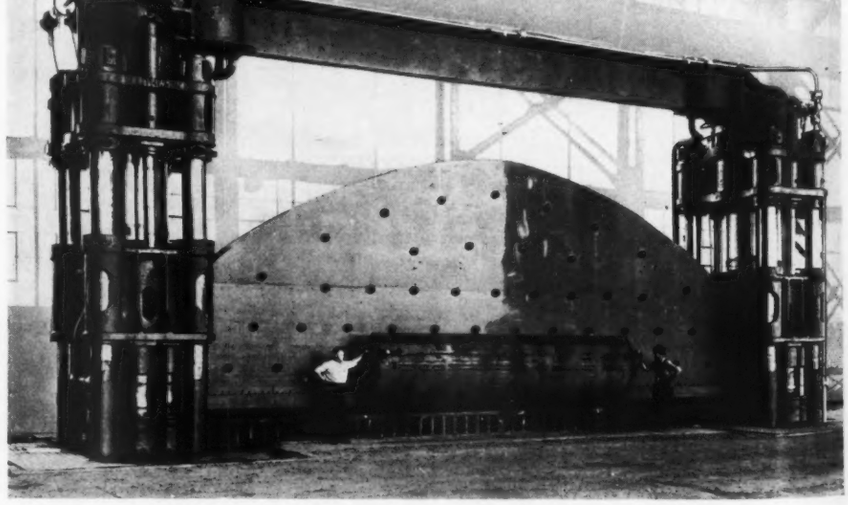
The two Southwark built presses have 50-in. diameter rams, operating under 3,000 lb. hydraulic pressure. The forged steel columns are 16 in. in diameter, and overall height of each press is 40 ft., of which 15 ft. extend below the floor line. Weight of the material used in the construction of the two beams is 1,000,000 lb. approximately.

Features in the design of this press are an arrangement for equalizing the pressure on both main cylinders to compensate for eccentric loading; and a special swiveling and thrust block design on the moving beam, which permits eccentric loading without throwing any side strains on either press. Each press has a 15-ft. square base and is of all cast steel and forged steel construction.

New Compound-Wound Motor for Trolley Coaches

A COMPOUND-WOUND motor for trolley coaches, which provides both speed control and electric braking to operate in coordination with the air brakes, was recently announced by the General Electric Company. Tests in revenue service conducted in Columbus, Ohio, indicated that the electric braking provided by the new motor should extend the life service of the brake-shoes by 400 to 600 per cent.

In addition to the usual series winding, the motor employs a shunt winding separately excited from the trolley. Braking is controlled without undue



6,000-ton capacity Baldwin-Southwark press installed in the Chattanooga plant of the Combustion Engineering Company

axle stress, and rheostat losses are minimized. Power consumption with the new motor is approximately 15 per cent less than with present single series motor equipment.

In operation, the motor becomes a generator when the operator lets up on the power pedal, and pumps current back into the line, retarding the speed of the coach. The retardation is the same as is produced by the engine compression of an automobile during deceleration.

When braking, the motor generates into a closed resistance circuit and the braking effort is dissipated as heat. The brake pedal controls both the dynamic and air brakes, and initial pressure on the pedal applies enough air to take the slack out of the brake mechanism and crack the air ports. More pedal pressure gradually builds up the electric braking to full value, and full pressure gradually applies the air brakes.

MEETINGS

AMERICAN SOCIETY OF MECHANICAL ENGINEERS—*Fall meeting, Providence, R. I., Oct. 5-7. C. E. Davies, secretary, 29 W. 39th St., New York.*

AMERICAN SOCIETY OF TOOL ENGINEERS — *Semi-annual meeting, Pittsburgh, Pa., Oct. 14-15. Further information may be obtained from Ford R. Lamb, executive secretary, 2567 W. Grand Boulevard, Detroit, Mich.*

PORCELAIN ENAMEL INSTITUTE—*Eighth annual meeting, Cleveland, Ohio, Oct. 25-26. Further information may be obtained from the Institute at 612 N. Michigan Ave., Chicago, Ill.*

EXPOSITIONS

NATIONAL METAL CONGRESS AND EXPOSITION—*Convention Hall, Detroit, Mich., under the auspices of the American Society for Metals, Oct. 17-21. Further information can be obtained by communicating with W. H. Eisenman, secretary, 7016 Euclid Ave., Cleveland.*

Do You Know That—

A NEW FLAME-PROOFING LIQUID applied by dipping, spraying or brushing is being successfully used on stuffings of paper, leather, wool, cotton and other materials. The liquid forms a transparent film over each fiber and prevents lumping and sagging of stuffings, and does not crystallize and crumble. (94)

* * *

A NEW RUBBER-LIKE MATERIAL, possessing many of the properties of natural rubber, is not attacked by oils and grease nor affected by many acids and alkalis. Process utilizes a mixture of glycerine and tung oil, heated to about 410 deg. F. In place of tung oil, the patent states that soya bean oil and other vegetable oils may be used in the process. (95)

Case Histories in Patent Law

H. A. TOULMIN, JR.

(Editor's Note: *We wish to emphasize that in consenting to furnish this column wherein general explanations of the law in specific patent cases are set forth, Col. H. A. Toulmin, Jr., wants it clearly understood "that each actual case should be submitted to your own patent attorney who is the only one familiar enough to advise you accurately." The purpose of these explanations is to give a better general understanding of questions of patent law.*)

QUESTION: When is "change in degree" patentable, and when is it not?

ANSWER: Whenever change in degree arises in the design of a device you should submit all of the facts concerning your particular problem to your patent attorney, for to the layman the various court decisions often seem to be utterly without consistency. Yet the rules laid down by the courts are in truth beautifully consistent and wholly logical.

Even a considerable change in degree is usually not patentable if it merely results in making a device lighter, faster, cheaper, simpler or more portable. That amounts merely to refining the invention, usually by applying common knowledge or technical skill—by doing, in short, what any engineer or mechanic acquainted with the art would naturally strive to do. The Supreme Court denied the validity of a patent on an agricultural implement in the following words which have since so often been quoted by the courts that they practically constitute a rule: ". . . if there was any change of construction suggested, it was only to increase its capacity for usefulness; that it was a carrying forward of new or more extended application of the original thought—a change only in form, proportions, or degree, doing the same thing in the same way, by substantially the same means, with better results."

A well-known case involved a machine on which part of the mechanism showed a tendency to reverse. This was overcome by making a hand-wheel heavier. The court said that this effect was well known and that it "sprang naturally from the expected skill of the maker's calling, and this use of the heavier wheel did not make the mechanism in any proper sense a new thing evolved by the inventive faculty. (It) was not the product of a creative mental conception but merely the exercise of the ordinary faculties of reasoning upon the materials supplied by a special knowledge, and the facility of manipulation which results from its habitual and intelligent practice."

But no matter how slight the change may be, and how obvious it may seem after it is accomplished, it is patentable if it turns failure into success.

The length of the step taken is of no moment. Very great changes in the design of a mechanism are not patentable invention unless new and useful results are achieved.

A common tendency of laymen and even judges who are unversed in science and mechanics is to appraise the patentability of an invention by the length of the step taken, or by measuring it by the present state of the art rather than by its state when the inventor took the little step which turned a long series of fruitless experiments into a workable, new thing. What would today be common scientific knowledge and so not patentable may very well have involved a bold flight of imaginative inventive genius only a few years ago when the successful inventor took the last little step.

It is therefore imperative, in judging whether change in degree is invention to know thoroughly the state of the art then—not now.

A classical example of slight change in degree being patentable is that of the inventor who increased the angle of slope of the Fourdrinier wire in paper machines. The slight slope formerly used was to control the dryness of the web of paper. By increasing the pitch the drying was accomplished in half the distance with the result that ripples in the stock were eliminated and the speed of production greatly increased. The step taken was slight in degree but it had escaped paper makers for many years and resulted in a revolutionary change in the art. This, the Supreme Court said, was invention.

To sum up: the law rightly holds that invention depends upon the ability to perceive even a slight change that will produce new and useful results, and that seemingly great and complex changes will not be patentable invention unless they accomplish this result by virtue of exercise of the inventive faculty.

New Materials and Parts

New Nickel Alloy

Known as "Z" nickel, this alloy in the annealed condition fabricates as easily as nickel and can be heat-treated after fabrication with little or no distortion as heat-treating temperatures do not exceed 930 deg. F. Discoloration in heat-treatment can be avoided by hardening in a hydrogen atmosphere. Produced in soft, half hard, or full hard tempers with minimum tensile strengths of 90,000, 130,000 and 155,000 lb. per sq. in., respectively. The strength and hardness is increased with cold reduction. Being of the precipitation hardening type, quenching from 2,000 deg. F. is required to render the alloy suitable for heat-treatment and for the convenience of users, the alloy may be obtained from the mill already quenched and suitable for fabrication of parts which can be hardened in finished or semi-finished form. Close temperature control, plus or minus 10 deg. F., is required in hardening "Z" nickel. Tensile modulus of elasticity is 30,000,000 and torsional modulus is 11,000,000. Available in hot rolled or cold drawn rods, cold drawn wire and cold rolled strip. The International Nickel Co., 67 Wall St., New York, N. Y.

Induction Motor

A line of shaded pole induction motors designed for higher efficiency and long life under severe running conditions. Special features include triple shading and improvements in rotor and stator design, in addition to which these "YAr" motors employ the integral bridge and heavy shading characteristics of the Barcol motors. Have self-aligning, oil-and-graphite impregnated bearings, and wick type oilers with sufficient capacity for six months continuous operation. Shaft is hardened stainless steel. "YAr" motors are available in three frame sizes covering a horsepower range from 0.005 to 0.026 hp. (4 to 20 watts) output. Barber-Colman Co., Rockford, Ill.

Variable-Speed Transmission

A line of oil power variable-speed transmissions claimed to have an extremely wide speed range. They develop high torque with smooth operation at slow speeds as well as higher speeds

and provide high mechanical efficiency throughout the entire speed range. Instant reversal at high speeds on continuous duty is also claimed. Operating temperatures are low for either continuous or intermittent duty. Transmissions are housed in a small compact case and may be controlled either automatically or manually. Model 5HT, illustrated, is rated as a 5 h.p. unit, providing a speed range from 3 to 2,400 r.p.m. Additional sizes available are a 2 h.p. unit and a 10 h.p. unit. Sundstrand Machine Co., Rockford, Ill.

Round Composition Belting

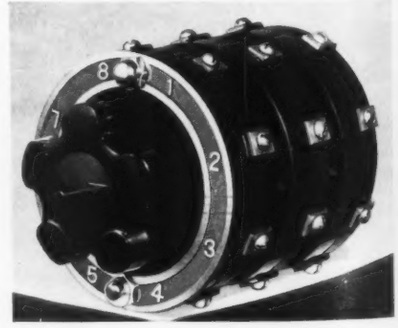
Advantages claimed for this new round composition belting include uniform quality, absolutely round, less subject to stretch, and requiring no metal fasteners. The inner core is made of a strong flexible material which will stand an indefinite amount of flexing. The core prevents the belt from stretching, yet it drives the machine with less belt tension, having a greater coefficient of friction than leather belting. For fastening the ends of the belt two inches of the composition is removed and the ends of the core tied together. Sudbury Laboratory, South Sudbury, Mass.

Welding Electrode

A new welding electrode, Smootharc "Har-Ten," designed for alloy steel work. The base metal contains alloying elements which precipitate from solid solution at certain temperatures, increasing hardness and ultimate strength. Tests show that welds made with "Har-Ten" and heat-treated for one hour at 950 deg. F. increase yield point from 68,500 to 92,500 lb., ultimate tensile strength from 83,000 to 102,250 lb., while the percentage of elongation in 2 in. decreases from 15.5 to 14.8 under the heat-treatment. Two types are available, Type A for flat, vertical and overhead positions; Type B for flat work only. Both are available in sizes from $\frac{1}{8}$ to $\frac{1}{4}$ in. in diam. and are manufactured in 14 in. lengths. Harnischfeger Corp., 4400 W. National Ave., Milwaukee, Wis.

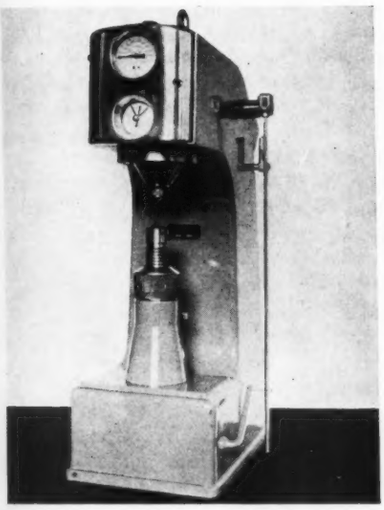
Current Control Switch

A new 30 amp. rotary type current control switch. Massive $\frac{1}{2}$ in. brass contacts are molded into non-carbonizing composition, claimed to be capable of withstanding 30,000 volts per in. thickness. Fully inclosed construction reduces the possibility of contact burning as oxygen is effectively excluded from contacts. In the ganged type current control switch for polyphase "Y" connected circuits, all output current regulation is controlled by one insulated control handle of molded plastic construction. This results in simplified operation and assures perfect balance in all three phases. Ganged type switch, illustrated, has a 4 in. outside diameter, and the overall length from front of knob to back cover of switch is $5\frac{1}{4}$ in.; the single unit type, 4 in. outside diameter and overall length, $2\frac{1}{4}$ in. Kneisley Electric Co., Toledo, Ohio.



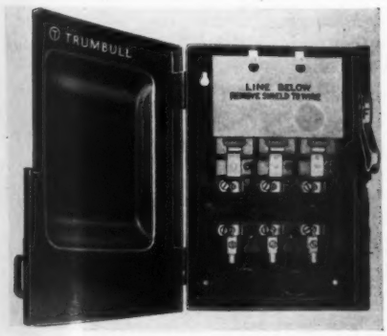
Hardness Tester

A direct reading motor-operated Brinell hardness testing machine designed especially for production usage. Piston is of the ground, packless, self-guided type, the operating mechanism being designed to eliminate the use of a piston return spring. Work screw and screw support may be locked rigidly. Adjustment of both primary and test loads may be effected instantaneously from the outside of the machine without dismantling or disturbing anything else. All piping and operating valves are within the body of the machine. Hydraulic pump is of the rotary gear type driven by a standard 1/3 hp., 120 volt, 1,725 r.p.m. motor through a flexible coupling. Operating valve is connected to the foot treadle. Clutches and solenoids have been eliminated and readings are direct. Detroit Testing Machine Co., 5137 Trumbull Ave., Detroit, Mich.



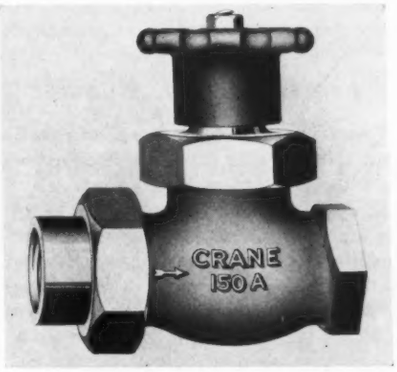
Safety Switch

An improved, heavy-duty industrial switch, Type RBA, to supersede the RB line. New features claimed for the switch include: interior mounted on a removable saddle with all terminals accessible from the front, for convenience and ease in wiring; a convenient operating handle combining the advantages of front and side operation, saving space, providing for close ganging; heavy cover catch and releasable interlock; wire gutters, free from moving parts; and solderless connectors. Unit is inclosed in an attractive heavy steel box of artistic design with machine gray baked enamel finish for fine appearance. Rated at 30 to 600 amp. at 230 to 575 v., a.c. or 250 to 600 v., d.c. Circular 300 available. The Trumbull Mfg. Co., Plainville, Conn.



Brass Globe Valve

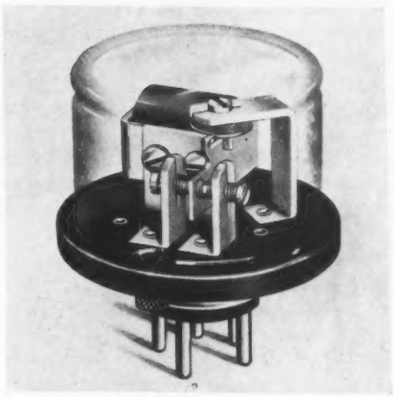
Designed for air installations where quick-opening, quick-closing valves are needed. An apron on the wheel protects the upper part of the valve from rough handling and a brass screen in the union connection at the valve inlet keeps out foreign matter. The protective apron extends down over the packing nut, stuffing box and the top end of the bonnet. The union bonnet connection is said to make possible easier dismantling and reassembling of the valve. A spring maintains a constant load on the stuffing box packing. Valve is made in 3/4 and 1 in. sizes and is recommended for 150 lb. air working pressure. It should be installed with the pressure above the seat. Crane Co., 836 S. Michigan Ave., Chicago, Ill.



"Galvo-Cleen" and "Rust-Solv"

Two new products, "Galvo-Cleen" for cleaning and preparing for painting new and old galvanized metal, zinc, die-castings or other metal containing a large percentage of zinc. Insures a perfect bond for the paint so that new galvanized metal can be painted as soon as installed, no special paint or primer being required. "Rust-Solv," a semi-paste rust solvent that can be applied with a spray gun or a brush and which will remain moist long enough to dissolve the worst degree of corrosion. For use on all types of metal surfaces, chromium plating, brass, copper and porcelain. Nielco Chemical Co., 5411 Cicotte Ave., Detroit, Mich.

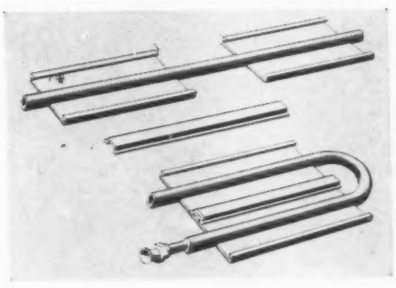
Sensitive Relay

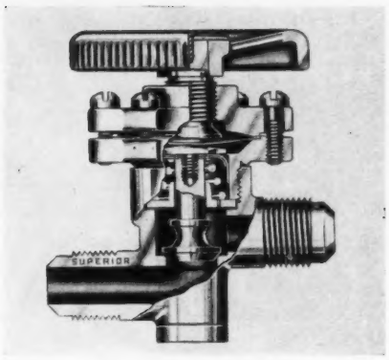


Designed to meet the demand for a compact instrument of rapid, positive action at low power input, Type 3-A relay is particularly adaptable for electronic and delicate control applications. Single pole, double throw switching is provided by the relay. Current is carried by the heavy hairspring to the movable contact mounted on the armature. The center hinge supporting the armature, does not carry current. The fine silver contacts of the relays are of adequate size to handle their full rated loads. Type 3-A is designed to control 150 watts non-inductive load at 110 volts a.c. with an input of 12 milliwatts d.c. Relay is housed in a dustproof metal case, with a transparent top and finished in black, to harmonize with panel and instrument assemblies. Case is 2 3/8 in. diam. and 2 1/4 in. high exclusive of the five mounting prongs. Sigma Instruments, Inc., 388 Trapelo Road, Belmont, Mass.

Extruded Flange Tubing

Aluminum tubing with integral flange to increase heat radiating capacity, and giving high heat transfer efficiency because coil and flange are integral. Strips can be bent to form 180 deg. arcs as shown in the illustration. This new coil construction has been tested as high as 2,800 lb. per sq. in., making this type of tubing suitable for both steam tables operating at a high pressure or for low pressure circulation of a refrigerant. Available either as tubes in lengths up to 80 ft. or more or in coils. Bohn Aluminum & Brass Corp., Detroit, Mich.





Diaphragm Packless Valve

Designed especially for use in refrigeration and air-conditioning systems. All valve parts subject to refrigerant pressure are made of hot forged brass to assure uniform density and freedom from seepage leaks. The multi-dissimilar-metal diaphragm forms a metal-to-metal seal between the auxiliary body and the bolted bonnet. The bonnet is readily removable, with refrigerant vapor or liquid pressure in the refrigeration system and in the valve, by virtue of the pressure cups located between the flow area of the valve and the diaphragm chamber. The complete internal assembly of the valve may be removed for installation. The valves measure 3½ in. high when fully opened and are available in sizes from ⅛ to ⅝ in. Descriptive Bulletin R2-D available. Superior Valve & Fittings Co., 504-37th St., Pittsburgh, Pa.

Improved Clutch

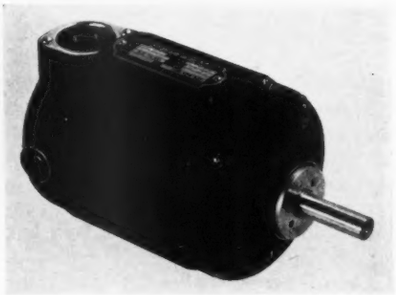
Known as the Taperoll clutch, wherein the tapered rolls are free to float in two directions. These taper rolls, when forced into engagement, do not grip instantly, but are retarded to relieve the motor, or other prime mover, from the sudden shock load. Three hardened steel tapered rolls are carried in a sleeve that is free to slide horizontally over a fixed hub. This sleeve is controlled by toggles connected to a sliding collar, which in turn is actuated by a standard shift collar and suitable pivoted lever for operating the clutch. The toggles provide efficient engagement, which automatically lock to hold the sleeve in operating position. Any type of transmission drive may be driven to or from this clutch. A liberal size hub is provided on which may be mounted a pulley, sheave or any type of gear. These may also be cast as part of the clutch body. Two sizes, rated at 3 and 6 h.p. at 100 r.p.m. or 15 and 30 h.p. at 900 r.p.m. Descriptive leaflet available. Ramsey Chain Co., Inc., Albany, N.Y.

Cup Point Setscrew

Available with knurling all around the points. When turned into place the knurled edges effectively grip the shaft in such a manner that loosening or backing-off is claimed to be impossible except by the application of a wrench. Screws may be re-used in the same holes indefinitely. A wide range of sizes available. Standard Pressed Steel Co., Box 545, Jenkintown, Pa.

Fractional Hp. Motors

Types W and W2 motors, especially adaptable for high-speed drives, flexible-shaft tools, grinders and set-ups where high speed without vibration is a factor. High precision, grease-sealed ball bearings are mounted in steel sleeves molded in the aluminum housings. Preloading springs eliminate end play and compensate for wear. Line leads are not brought outside the motors but to two-pole male connectors mounted in the housings. They are of the plain series universal type. Type W is rated at 1/3 h.p. d.c. a.c. or ½ h.p. Type W2 is ½ h.p. a.c. or 2/3 h.p. d.c. at continuous duty. Descriptive Bulletin 401-A available. The Dumore Co., Racine, Wis.



Thermal Plug Fuse

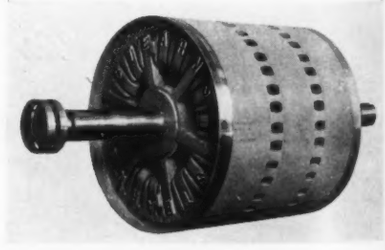
A new Trico-Matic thermal time-lag fuse with built-in thermal overload cut-out. This thermal cut-out holds starting and momentary overloads, yet gives safe and dependable protection on prolonged overloads, making overfusing unnecessary. On short circuits the fuse element operates the same as an ordinary fuse. The unit is approved by Underwriters' Laboratories, Inc. Trico Fuse Mfg. Co., Fifth St. at Chambers, Milwaukee, Wis.

Automatic Time Switch

A short-cycle, automatic, repeating timer, Type TSA-14, designed to control electric circuits without respect to the time of day. Mechanism consists of a contact-making mechanism driven through a spur-gear train by a Telechron motor. The contact-making mechanism consists of brushes which bear on rotating cams. The silver contacts mounted on these brushes are snapped "open" and "closed" by means of steps on the cams. Housed in a die-cast base with a glass cover, suitable for either indoor or outdoor installation. The silver contacts are rated 10 amp. at 230 volts. For circuits having higher ratings a suitable relay should be used in conjunction with the timer. General Electric Co., Schenectady, N. Y.

Magnetic Pulley

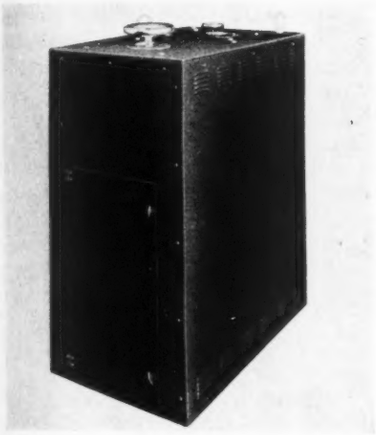
An improved high-duty magnetic pulley designed to allow for greater radiation area by means of a new ribbed construction, including deeper coil pockets which allow for more copper wire and more ampere turns with subsequent greater magnetic strength. Coil windings are claimed to be more efficient because of the greater cooling area furnished by the forced air circulation. Windings are completely surrounded by steel. Another feature of the improved pulley is the non-magnetic end rings of special alloy steel which extend beyond the active face of the pole and are machine fitted to the end poles. These heavy non-magnetic wear-resisting end rings provide a support for the unloaded edges of the belt at either side and confine the magnetic



force of the pulley to the active portion of the belt. Unit is weather-proof, special gland type fittings seal the lead-in wires against moisture, and voids under the coil covers are filled with high-temperature melting compound. Available in a wide range of diameters and face widths to accommodate any type of existing conveyor system. Stearns Magnetic Mfg. Co., Milwaukee, Wis.

Transformer-Type Arc Welder

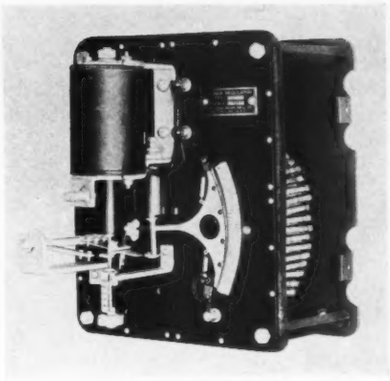
An alternating current arc welder of the transformer type, known as the "Trans-Arc," which it is said offers an exceptionally low open-circuit voltage for greater safety and a relatively high closed-circuit voltage for maintaining the arc. It employs condensers in conjunction with a welding transformer, and the welding current is controlled by means of a voltage regulator which varies the voltage across the condensers. The Trans-Arc is completely self-contained in a compact sheet-metal case equipped with lifting lugs. Manufactured in 150, 300



and 500 amp. for operation on either 230 or 460 volts, 60-cycle circuits. Descriptive folder available. American Transformer Co., 178 Emmet St., Newark, N. J.

Voltage Regulator

A simple, inexpensive "Rocking Contact" type voltage regulator, known as Type V-O, designed for automatic voltage control of small alternating and direct current generators. It is quick-acting, regulating the voltage by directly varying the resistance in the field circuit. The regulator consists of a sensitive solenoid actuated plunger which acts upon a main shaft, rocking a special carbon rimmed contact sector over the inner surface of a commutator, the segments of which are connected permanently to the regulating resistance. The segments are heavily silver plated in order to insure positive con-



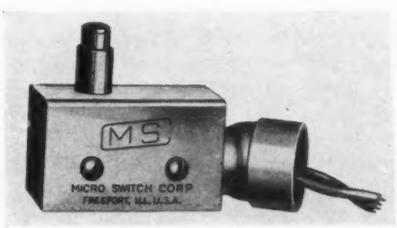
tact surface and are insulated one from another and solidly held in place on a specially constructed base to prevent any disalignment. Regulator is inclosed in a metal case and is suitable for either switchboard or wall mounting. Descriptive Leaflet No. 2326 available. Allis-Chalmers Mfg. Co., Switchgear Div., Milwaukee, Wis.

Oil-Resisting Portable Cord

A new type of oil-resisting portable cord, Type OS, having a tough jacket of Glyptal-Neoprene, containing no rubber, providing resistance to mechanical as well as chemical injury. It is mold-cured in lead directly over the core and is given a waxed finish. The core is similar to that of the Type S, having extra flexible stranded copper conductors. General Electric Company, Schenectady, N. Y.

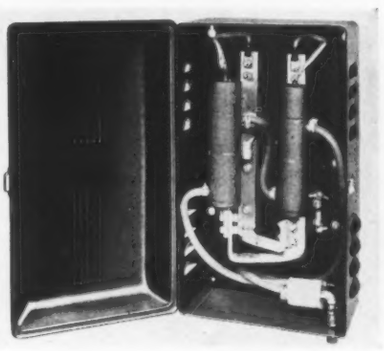
Metal-Clad Limit Switch

Especially suitable for exacting service on automatic machinery, this new Series Q Micro limit switch has an overtravel of ¼ in. It has a 5/16 in. diam. actuating plunger which can be moved ¼ in. beyond the operating point without straining the snap action mechanism, changing its characteristics, or without affecting its life. A pretravel of 0.015 in. movement with an operating pressure of 7 to 8½ oz. and a movement differential of 0.0002 in. to 0.0003 in. is required to operate the switch. Contact arrangements can be for normally closed, normally opened, or double throw circuits. Switch is sealed in a metal housing with right or left-hand angle conduit fitting. Overall dimensions 2⅛ in. high, 1 in. wide and 3¼ in. long. Micro Switch Corp., Freeport, Ill.



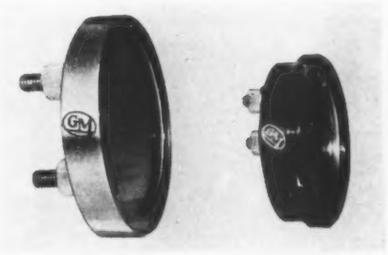
Electronic Welding Contactor

A low-cost "Weld-o-trol" electronic power switch for controlling the primary circuit of welding transformers. With either sealed-off or continuously pumped ignitron tubes, the unit offers an instantaneous power switch for producing uniform welds, and is free of moving parts, arcing contacts and noise. Available ratings are roughly equivalent to 300 and 600 amp. conventional welding contactors. The weld-o-trols equipped with sealed-off tubes consist of a sheet metal cabinet in which are mounted a bus bar assembly, electrical connections and a flow switch. The assembly is of the same general construction for all tube ratings. but has copper and construction suitable for the current ratings involved. Only electrical connections required are: one power cable entering the unit and one leaving the unit, and two control leads from the timer. The assembly with sealed-off tube is available either open or inclosed. The open type is recommended for applications requiring that the assembly be mounted inside a welding machine or with other auxiliary control. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.



Barrier Type Photocell

Two new barrier type cells, claimed to have twice the output of preceding units. Type F2A has a non-tarnishable metal case, Type F3 a molded plastic case. When desired, both cells can be sup-



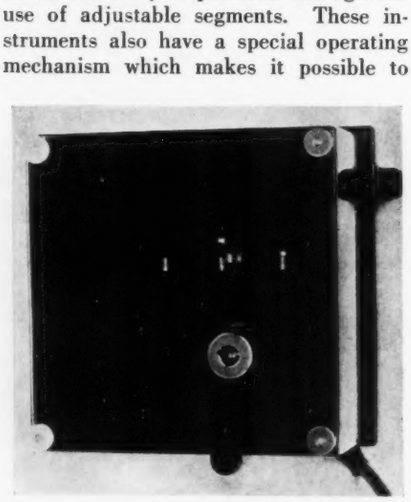
plied with visual filters to give them a color response equivalent to that of the human eye. Bulletin CS604 available. G-M Laboratories, Inc., Dept. NR, 1731 Belmont Ave., Chicago, Ill.

Hand Tachometer

Covering a range of speed from 30 up to 40,000 r.p.m., with only three tachometer ranges, claimed to be equivalent in speed coverage to six-range hand tachometers. This is done by allowing the indicating pointer to make two turns around the dial instead of one, thereby making the scale 13 in. long. This new "Jagabi" universal hand tachometer operates on the same centrifugal or fly-wheel governor principle as the Type C tachometer. The indicating dial is 3 in. in diameter. The instrument is supplied complete with carrying case and accessories. Two ratings are available, 30 to 40,000 r.p.m. and 25 to 30,000 r.p.m. Descriptive Bulletin 1575 available. James G. Biddle Co., 1211-13 Arch St., Philadelphia, Pa.

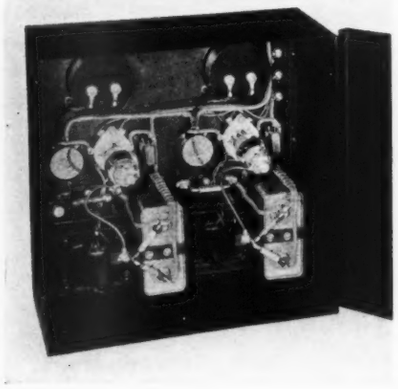
Air-Operated Cycle Controller

A new single-cam cycle controller that provides for the control of as many as four separate operations, developed for process manufacturing. The cam is designed to be cut so that it will meet a wide variety of requirements. Additional flexibility is provided through the use of adjustable segments. These instruments also have a special operating mechanism which makes it possible to obtain two different speeds of rotation before the cam completes a cycle. They are equipped with patented three-way leakless pilot valves, eliminating the need for a fixed air leak at the controller. The Bristol Co., Waterbury, Conn.



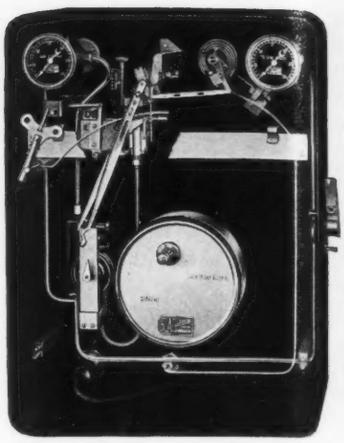
RayTimeR

For measuring the duration of electrical impulses, the time during which an a.c. circuit is energized being shown directly on a meter scale in the instrument. It may be calibrated in either cycles or seconds and covers with equal precision excitation periods from 1/120th of a sec. to 30 sec., the accuracy being plus or minus 5 per cent. Instrument is a simple electronic device with no moving parts except the indicating pointer and requires no maintenance other than the occasional replacement of the vacuum tube. Illustration shows a double unit having two RayTimerRs assembled in one container for convenience in measuring two different impulses simultaneously. Single units are also made. Raytheon Mfg. Co., 133 Willow St., Waltham, Mass.



Controlling Instruments

A line of TAG recorders and recorder-controllers with 10 and 12 in. charts. Special features of the new recording thermometer and pressure gage include interchangeable calibrated tube system that can be readily replaced and need be checked at one point only; stainless steel pen arm that can be removed easily for cleaning or replacement; precision-built capillary fountain pen designed with draftman's split-nib; pen arm movement designed for strength, lightness and rigidity supported by bearings at both ends. The recorder-controller is offered in either the "On-Off" or throttling control model. The "On-Off" model with the simple non-adjustable flapper fits all ordinary temperature control applications. The throttling model utilizes an adjustable calibrated flapper which provides



an exact sensitivity adjustment. This design permits easy adjustment of the throttling range to coincide with any considerable apparatus lag. Complete details in Catalog 1060D. C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.

Coated Cover Glass

A specially treated glass processed on one side, claimed to be immune to pitting, resistant to heat and to outlast ordinary glass 10 to 50 times. Available in standard 2x4¼ in. plates and 50 mm. round lenses. Also may be cut to required sizes for grinding wheel guards, automatic welding machines, or special helmets and goggles. Maximum area available is 10x10 in. Mine Safety Appliances Co., Braddock, Thomas & Meade Sts., Pittsburgh, Pa.

High Lead Bronze

A bearing metal alloy containing 70 per cent copper and 30 per cent lead with no tin content and containing less than 0.2 per cent total impurities. Reported laboratory tests show these bearings to withstand more than 3,500 lb. per sq. in. pressure on the projected area at 900 ft. per min. running speed. A distinctive feature is claimed to be the fine distribution of lead through the copper matrix, the alloy having a hardness of 22 Brinell, using a 500 kg. ball. Available in bar stock or individual castings to specifications, either finished or unfinished castings. Fredericksen Co., Saginaw, Mich.

Flexible Shellac and Casein

Flexilac, an orange colored, non-inflammable, viscous resin which dries quickly to give a flexible, glossy adhesive film which is water-soluble but not affected by hydrocarbons. It may be used in cements for gaskets exposed to gaso-

line and naphtha, in special adhesives, polishes, insulation, and for finishing metal, paper, textiles, rubber, etc. It may also be used as a suspending agent for pigments for coloring and glazing china, porcelain and glass.

Protoflex is a straw-colored transparent jelly which dissolves readily in water (without heat). Such a solution dries rapidly to give a flexible almost colorless transparent film. No alkalies or solvents are needed. It has a pleasant odor and will keep indefinitely without spoilage and is free from solid particles. Its uses are as indicated for Flexilac. Glyco Products Co., Inc., 148 Lafayette St., New York, N. Y.

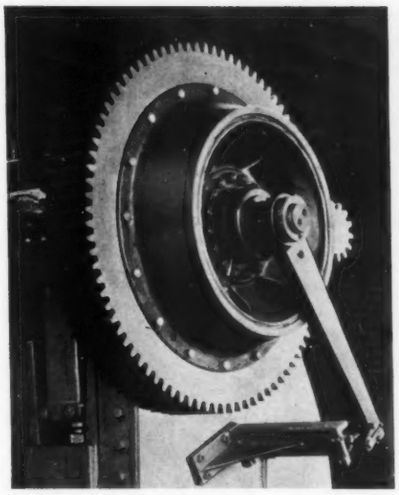
Continuous Blueprinter

Complete machine consists of a washing and drying attachment, which has been added to their printer, introduced a year ago. Complete machine is in three units and the printing unit may be purchased separately. Printing speed ranges from 9 in. to 12 ft. per min. New type plate glass transmits 20 per cent more actinic rays to the sensitized paper, and the three 16 amp. arc lamps are of a new type equipped with reactance coils. After passing through the washer, wringer rolls

remove surface water from prints before entering dryer wherein copper heating drums provide a quick uniform distribution of heat furnished by electric heating elements. Driving motor is constant speed with drive through Reeves variable-speed pulley and a gear reduction running in oil. Bearings are Oilite and require no oiling. The Shaw Blue Print Machine Co., Inc., 9–11 Campbell St., Newark, N. J.

Friction Clutch

A new servo-action punch press clutch which it is claimed combines the shockless, instant-engagement and durability of the friction clutch with the positive action and simple operation of the conventional jaw or pin clutch. It is operated in the same way as a press using the



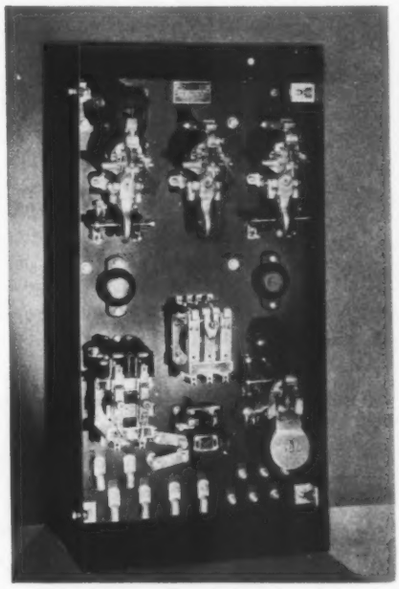
jaw or pin clutch. The purpose of the servo-mechanism is to utilize the high torque loads of the press to boost the engaging pressure between the clutch surfaces to a value sufficiently high to transmit without slipping any torque that the clutch is capable of handling. The servo-mechanism which forms the hub of the inner clutch cone, comes into operation after the initial engagement of the clutch surfaces under spring pressure. This spring pressure is just sufficient to overcome the inertia of crank and ram and the friction of the band brake. The servo-action automatically loads the clutch to an amount just sufficient to perform the work, resulting in increased life of the facings and other parts. Descriptive bulletin available. Industrial Clutch Co., Waukesha, Wis.

Pushbutton Station

Type HD heavy-duty, explosion-proof pushbutton stations suitable for use in corrosive atmospheres and in Class I, Group D hazardous locations, designed in accordance with the requirements of the Underwriters' Laboratories. Available with from one to four station pushbutton units of the momentary contact type, or with maintained contact units. In addition, stations are available with two or three position selector switches which are available either as single-pole, double-throw switches or double-pole, single-throw switches. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

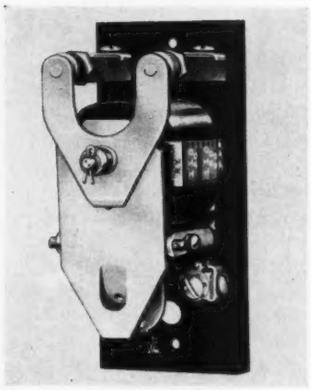
Heavy-Duty Controller

A line of d.c. heavy-duty controllers for all machine tool applications, for heavy-duty applications below 10 hp. and for general purpose above 10 hp. A new timing device which operates magnetically on the principle of a condenser discharging through a magnet coil provides simple, positive, precise, definite time acceleration which is unaffected by load, temperature or other working conditions. Once adjusted to obtain the desired starting period the controller will always accelerate in this same time. These controllers conform with the new NEMA standards for machine tool and general purpose service, and include non-reverse and reversing types, with and without dynamic braking, for both constant speed and adjustable speed motors. Available for use with either pushbutton or drum type master switch and in all standard NEMA ratings up to 75 hp., 115 volts; and 150 hp., 230 and 550 volts. Cutler-Hammer, Inc., 296 North 12th St., Milwaukee, Wis.



Non-Peeling Paints

"Wet-X-Hale" paints, enamels and varnishes made in regular and special types, for application to most surfaces that are wet, damp or dry, giving non-peeling and protective adhesion. When applied to moist or wet surfaces they absorb the moisture contacted, while painting. The paint-film when set and dry will be protected against water reversing, will not peel, blister or crack, and provides rust-protection when applied to iron, steel and other metals. Wet-X-Hale paints can also be furnished with additional features to meet and combat destructive elements in the air and other adverse conditions. Wet-X-Hale Paint Compound Co., 15 Moore St., New York, N. Y.

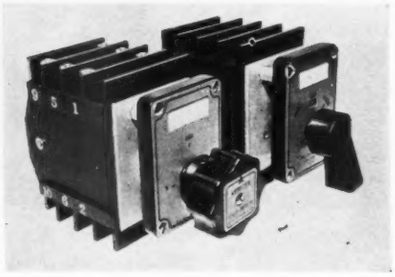


Heavy-Duty Relays

Bulletin 132 relay, developed for heavy-duty service on a.c. and d.c. circuits. Large gap, silver-to-silver, self-aligning contacts with adequate surfaces and pressures to break 30 amp. and insulating material to withstand 2,500 volt dielectric test make these relays suitable for light contactor duty. Relays are available with normally open or normally closed contacts. Double pole with common feed and single pole with contact combinations can be furnished. Listed for 6, 12, 24, 32, 115 and 230 volts a.c. and d.c. Ward Leonard Electric Co., Mt. Vernon, N. Y.

Rotary Switch

Type R-2 instrument and control switches, available in types to completely cover the field of apparatus control, whether the requirement is standard or special, on circuits up to 600 volts. Type R-2 instrument switches, shown to the left in the illustration, are used on all types of instrument transfer for voltage and current coils. By a selection of suitable cams, switches can be built up for any number of applications. Type R-2 control switches, shown to the right in the illustration, are made in two styles depending upon the application. The circuit breaker control switches include the



quick break feature for long life on heavy-duty service such as closing and tripping circuits for circuit breakers. The governor, rheostat and miscellaneous control switches differ from the circuit breaker control switches in that they are built like the instrument switches with the spring return feature instead of the position locator. Switches are easily mounted on panels, 1/8, 1, 1½ and 2 in. in thickness. Slip-on molded plastic side plates protect contacts from dirt accumulation and allow instantaneous inspection. On the instrument switches, handle plates are supplied which identify the switches. Face plates are supplied with standard position markings. Catalog 9 available. Roller-Smith Company, 233 Broadway, New York, N. Y.

Manufacturers' Publications

BEARINGS—Boston Gear Works, Inc., North Quincy, Mass. Catalog Form 4-38, 16 pages, 3½x6 in. A revised catalog of their Oilite oil-cushion precision bronze bearings to supersede Form 1-38.

BEARINGS—E. A. Williams & Son, Inc., 111 Plymouth St., Jersey City, N. J. Leaflet containing data on their graphite and bronze oil-less bearings made in grooved and drilled types.

FASTENINGS—The Rawlplug Co., Inc., 98 Lafayette St., New York, N. Y. Catalog 38, "A Better Anchorage for Bolts and Screws," 38 pages, 3½x6⅛ in. Illustrating and describing the many different types of anchors and accessories for use in all kinds of materials. Also contains a section devoted to problems of fastening to masonry.

FELT—The Felters Co., Inc., 210 South St., Boston, Mass. Folder giving details on their Certified Felt and felt products.

GEARS—Charles Bond Co. 617-23 Arch St., Philadelphia, Pa. Catalog T-59. A new edition of the Bond Stock Gear Catalog covering gears, sprockets, speed reducers, flexible couplings and other industrial equipment. Data on their new line of "B" type double reduction speed reducers is also included.

G. E. BULLETINS—General Electric Co., Schenectady, N. Y. Bulletin GEA-2791A containing data on their Thyratron resistance-welder controls; Bulletin GEA-2026A on their brake-motor; and Bulletins GEA-2965 and 2966, on G-E thinly coated electrode, Type W-3, for high-speed arc welding, and sheath-coated electrode, Type A, for cast-iron welding, respectively.

LIGHTING EQUIPMENT — The Fostoria Pressed Steel Corp., Fostoria, Ohio. "Handbook of Localized Lighting," 24 pages, 8½x10 in. Containing a brief discussion on localized lighting and its advantages, followed by detailed information, illustrations and tables of specifications covering Fostoria Localite units.

MICARTA PRODUCTS—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Descriptive Leaflet 63-020, 4 pages, 8½x11 in. Listing the standard sizes, colors and finishes of Micarta plate, and tabulating the physical and electrical properties and applications of Micarta plate, Micarta rod, channels, angles and tubing.

"NICKEL ALLOY STEELS"—The International Nickel Co., Inc., 67 Wall St., New York, N. Y. A revision of Data Sheet Section III, No. 1, "Properties and Uses of Some Cast Nickel Alloy Steels," for their data book "Nickel Alloy Steels."

PUMPS—Goulds Pumps, Inc., Seneca Falls, N. Y. Bulletin containing complete description of their new line of Fig. 3390 centrifugal pumps.

SCIENCE SUPPLIES—Central Scientific Co., 79 Amherst St., Boston, Mass. Booklet, 40 pages, 11x7¾ in. Their latest order book for scientific supplies for use in the physics, chemistry and biology laboratories.

SOCKET SCREWS—The Bristol Co., Waterbury, Conn. Bulletin 836. Covering Bristo socket set and cap screws, including price list, and briefly describing the principle involved in the multiple-spline design of these socket screws.

SOCKET SCREWS—The Holo-Krome Screw Corp., Hartford, Conn. Catalog 30, "Fibro Forged Socket Screws," 40 pages, 5x6½ in. Containing descriptive data, tables, and applications data of value to users of socket head capscrews, hollow set screws, socket head stripper bolts and hollow pipe plugs.

SPRAY EQUIPMENT—Eclipse Air Brush Co., Inc., Newark, N. J. Catalog 66, 32 pages, 9½x11 in. Complete information and illustrations covering their spray equipment and accessories.

STAINLESS STEEL—American Rolling Mill Co., Middletown, Ohio. Booklet, 16 pages, 8½x11 in. Containing valuable data regarding the heat-resisting grades of stainless steel, covering typical analysis, average physical properties, service at elevated temperatures, and recommendations for handling.

STAINLESS STEELS—Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill. An attractive booklet pictorially illustrating the possibilities of stainless steel for consumer products and industrial applications. Includes a brief summary of Allegheny stainless products carried in stock by Ryerson.

STEEL STAMPS—Nu-Method Steel Stamps, Inc., 149 Jos. Campau, Detroit, Mich. Bulletin 113-1, 4 pages, 8½x11 in. Illustrating and describing their line of Nu-Method steel stamps.

TEMPERATURE GAGES—Weston Electrical Instrument Corp., Newark, N. J., Bulletin, 12 pages, 8½x11 in. Containing complete information on their industrial temperature gages, general purpose and heavy-duty types. Laboratory thermometers for research and general laboratory use are also described.

VIBRO-INSULATORS—The B. F. Goodrich Co., Akron, Ohio. Catalog Section 7900, 8 pages, 8½x11 in. Covering their standard line of vibro-insulator rubber-to-metal type mountings, including types available, dimensions, and data to assist in the proper selection and installation of the mountings. Also includes photographs and descriptions of a variety of machines which have been mounted on vibro-insulators.

Books and Bulletins

Structural Aluminum Handbook

211 pages, 5¾x8½ in. Semi-flexible covers. Published by the Aluminum Company of America, Pittsburgh, Pa. Price $1.25.

This handbook is a compilation of the latest authoritative available data for the design of structures to be made of aluminum. It presents for the first time fundamental information regarding the ultimate strength of structural members fabricated from aluminum alloys, the data being based on laboratory investigations, field tests and extensive practical experience. It is a second edition of a handbook of the same name which appeared in 1930.

The data is grouped in five sections, namely, characteristics, manufacture, and fabrication of aluminum alloy structural products; design of aluminum alloy structures; elements of sections; technical data; specifications, tolerances, and commercial sizes of structural material. Section two covers the selection of working stresses, design considerations, and beam formulas. Section three covers the elements of all the usual shapes, rectangular sections, round tubing and plate girders. The technical data in section four covers sheets, bars, rivets, bolts and pipe. Conversion tables and other useful data are given in the appendix.

Principles of Engineering Economy

EUGENE L. GRANT. *Revised Edition. 431 pages, 6x9 in. Clothboard covers. Published by The Ronald Press Co., 15 East 26th St., New York, N. Y. Price $3.75.*

In the complete revision of this book the author has aimed to clarify the confused reasoning that seems to exist regarding certain fundamental principles of engineering economy. In presenting the subject the author has avoided the pure mathematical treatment. To explain the principle of cost comparison he resorted to illustrative examples.

The book is divided into four parts. Part 1 is primarily an introduction to the principles involved in planning engineering economy. Part 2 deals with the fundamental economics of the subject and is largely concerned with the subject of interest. Part 3 gives a great many examples that illustrate the procedure for determining relative costs. Many of the questions that must be answered when considering proposed new enterprises or the replacement of machines or structures are discussed. Part 4 covers three chapters, "Obstacles to Economy in Individual Enterprises," "Obstacles to Economy from the Social Viewpoint" and "Engineering Reports and Budgets."

Although prepared as a text, the book contains few formulas, devoting almost all of the space to explanatory discussions. It is well written and easy to follow.

Thermodynamics, Fluid Flow and Heat Transmission

HUBER O. CROFT. *300 pages, 6x9 in. Green clothboard covers. Published by the McGraw-Hill Book Co., Inc., 330 West 42d St., New York, N. Y. Price $3.50.*

Written primarily as a textbook, the first chapter is devoted to definitions of units encountered in thermodynamics and hydraulics, following which there is a chapter on dimensional analysis and the principle of similitude. The author then presents a few of the thermodynamics of perfect gases, following which he goes into the general differential equations applying to thermodynamics.

Other chapters cover the thermodynamics of vapors, analysis based upon the second law of thermodynamics, fluid flow and its measurement, the laws of heat transmission, the transportation of solids in fluids and the compression of fluids.

A brief appendix gives tables of critical constants, heat capacities and alignment charts for absolute viscosity.

Republic Alloy Steels

256 pages, 6¼x9¼ in. Flexible covers. Published by Republic Steel Corp., Cleveland, Ohio.

A new and complete handbook on alloy steels covering reference data on specifications, manufacture and applications. Fifty pages are devoted to some of the fundamentals of ferrous metallurgy such as the iron-carbon diagram, critical temperatures, effects of impurities in steel and heat-treating processes.

Twenty-six charts are presented giving the physical properties of different steels at different temperatures. Each chart is accompanied with tables giving the composition, approximate critical compounds and recommended thermal treatment. Charts cover all of the SAE steels in general use. Six additional charts deal with the mass effect on different SAE steels and Nitralloy G and Nitralloy H.

Other chapters include the McQuaid-Ehn grain size test, modern carburizing practices, impact tests, fatigue tests, gears and gear steel, steels used in the petroleum industries, railroad steels, Republic double-strength steel, aircraft steels, Nitralloy steels and stainless steels.

An appendix of 75 pages is devoted to tables and useful information.

Elements of Mechanism

THE LATE PETER SCHWAMB, ALLYNE L. MERRILL AND WALTER H. JAMES. *400 pages, 6x9 in. Clothboard covers. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York, N. Y. Price $3.50.*

This fifth revised edition follows in the main the same general treatment as in previous editions but gives a more thorough discussion of the laws of motion with special attention to acceleration. The order of the chapters has been rearranged with the aim of giving a more logical sequence.

Written as a college textbook, problems are given at the end of each of the thirteen chapters. Numerous examples are given to illustrate the application of formulas.

Subject matter covers linkages, cams, gears and gear trains, screw, wedge belt and chain drives, and numerous miscellaneous mechanisms such as wedge wheels and escapements.

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Gray Iron Specifications

Section 1, No. 1, "Nickel Cast Iron Data." 8 pages, 8½x11 in. Published by THE INTERNATIONAL NICKEL CO., INC., *67 Wall St., New York, N. Y.*

Presented as a guide to the selection of engineering specifications for gray iron castings.

Tenite Specifications

Edition 1B. 20 pages, 8½x11 in. Published by TENNESSEE EASTMAN CORP., *Kingsport, Tenn.*

A comprehensive booklet prepared to assist users of Tenite in determining the type of material best adapted to their particular requirements. Data on the chief physical properties of Tenite are presented in tables and graphs designed for ready comparison of the various types, formulas, and flows in which the material is regularly supplied.

New Wrinkles in Finishing

Vol. 1, No. 1. 12 pages, 8½x11 in. Published by NEW WRINKLE, INC., *Mutual Home Bldg., Dayton, Ohio.*

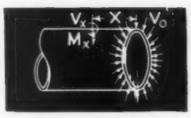
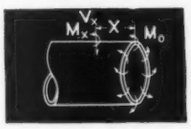
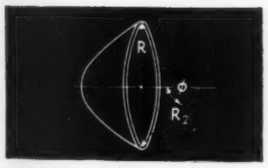
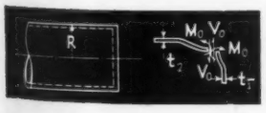
This first edition of the publication contains descriptive details concerning the new wrinkle finishes, illustrates and describes some of the numerous effects possible, and presents some typical applications.

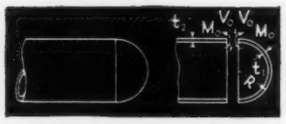
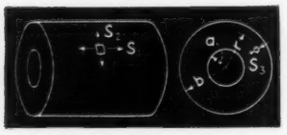
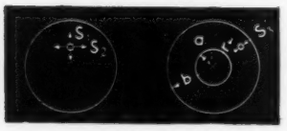
Stresses in Pressure Vessels—II

RAYMOND J. ROARK
Professor of Mechanics, University of Wisconsin

(Continued from page 360, September issue)

FORM OF VESSEL	MANNER OF LOADING	THIN VESSELS — LOCAL AND DISCONTINUITY STRESSES
CYLINDRICAL	**6.** Radial load P concentrated on small area of radius b and acting at a point remote from ends of cylinder	At points on loaded element (X axis): $s_1' = \left[1 - 1.1\left(\frac{x}{R}\right)^{1/6}\right] s_2'$: $s_2' = \frac{-P}{t^2}\left[0.42 \log \frac{\beta R}{x}\right]$ where $\beta = 0.215 + 0.5\left[\frac{y-b}{R}\right]^{1/8}$ At points on loaded circumference (Y axis): $s_1' = s_2' = \frac{-P}{t^2}\left[0.12 \log \frac{0.215\ R}{y}\right]$ Max. $s_1' = \frac{-P}{t^2}\left[0.42 \log \frac{0.215\ R}{b} + \frac{6\ \nu}{4\ \pi}\right]$ at load Max. $s_2' = \frac{-P}{t^2}\left[0.42 \log \frac{0.215\ R}{b} + \frac{6\ \nu}{4\ \pi}\right]$ at load At points on loaded element, Radial displacement $= -(0.135\ PR^2/Et^3)\ (e^{-\beta x})$ $(\cos \beta x + \sin \beta x)$, where $\beta = 0.3125/R$ Max. radial displacement $= -0.135\ PR^2/Et^3$ at load; Change in diameter for equal and opposite loads $= -0.27\ PR^2/Et^3$ **(Ref. 2)**
	7. Load as above but applied at a short distance e from an unsupported end of the cylinder	Max. s_1' = (Max. s_1' for load remote from end) $\left(\frac{e}{0.2\ R}\right)^{1/2}$ (when $e > 0.2\ R$, load may be considered remote from end). Max. s_2' = (Max. s_2' for load remote from end) $\left(\frac{0.7\ R}{e+b}\right)^{1/4}$ (when $e + b > 0.7\ R$, load may be considered remote from end). Radial displacement at load $= \frac{-P\ R^2}{E\ t^3}\left[0.48 - 0.22\left(\frac{e}{R}\right)^{0.35}\right]$ (when $e > 2\ R$, load may be considered remote from end). **(Ref. 2)**
CYLINDRICAL	**8.** Uniform radial pressure of p lb. per linear in. of circumference	Max. $M = \frac{p}{4\ \lambda}$ at load; Max. $s_1' = \frac{-3\ p}{2\ \lambda\ t^2}$ M_x = (Max. M) $[e^{-\lambda x}\ (\cos \lambda\ x + \sin \lambda\ x)] - 1/2\ P\left(\frac{1}{\lambda} e^{-\lambda x} \sin \lambda x\right)$ Radial displacement $= \frac{-p\ R^2\ \lambda}{2\ E\ t}$ Max. hoop stress $s_2 = \frac{-p\ R\ \lambda}{2\ t}$ at load. **(Ref. 3)**
CYLINDRICAL, WITH REINFORCING RING OF CROSS-SECTION AREA A	**9.** Uniform internal (or external) pressure of p lb. per sq. in.	$M_0 = 0.304\ p\ R\ t\left(\frac{A - c\ t}{A + 1.56\ t\ \sqrt{R\ t}}\right)$ ($M_0 = 0.304\ p\ R\ t$ for rigid ring or disk). $V_0 = 0.78\ p\ \sqrt{R\ t}\left(\frac{A - c\ t}{A + 1.56\ t\ \sqrt{R\ t}}\right)$ ($V_0 = 0.78\ p\ \sqrt{R\ t}$ for rigid ring or disk). Max. long. bending stress $= \frac{-6\ M_0}{t^2}$ at edge of ring. Formulas for Cases 10 and 11 may be used to find M_x, s_1' and V_x at other sections. Ring pressure per linear inch of circumference $= 2\ V_0$. (The above formulas are valid if rings are spaced so far apart that the influence of one does not extend to the next. This spacing $> 4/\lambda$. The sum of the direct and bending longitudinal stresses $s_1 + s_1'$ exceeds the normal hoop stress s_2 unless the ring spacing $< (\pi/2)\ (\sqrt{R\ t})$ **(Ref. 4, 5)**

FORM OF VESSEL	MANNER OF LOADING	THIN VESSELS — LOCAL AND DISCONTINUITY STRESSES
CYLINDRICAL	 **10.** Uniform radial shear or pressure V_0 lb. per linear in. of circumference	$M_x = 1/\lambda\ V_0\, e^{-\lambda x} \sin \lambda x$ Max. $M = 0.322\ V_0/\lambda$ at $x = \pi/4\ \lambda$ $V_x = V_o\, e^{-\lambda x} (\cos \lambda x - \sin \lambda x)$ $s_1' = 6\ M_x/t^2$; Max. $s_1' = 1.932\ V_0/\lambda\ t^2$; $s_2' = \nu\ s_1'$ $s_s = \frac{V}{t}$ Hoop stress $s_2 = \frac{-2\ V_0}{t}\left(\lambda\ R\ e^{-\lambda x} \cos \lambda x\right)$; Max. $s_2 = \frac{-2\ V_0}{t} \lambda\ R$ at end Radial displacement $= \frac{-V_0}{2\ D\ \lambda^3}$ $\theta = \frac{-V_0}{2\ D\ \lambda^2}$ **(Ref. 5, 6)**
	 **11.** Uniform radial moment M_0 in lb. per linear in. of circumference at end	$M_x = M_0\, e^{-\lambda x} (\cos \lambda x + \sin \lambda x)$; Max. $M = M_0$ at end. $V_x = 2\ \lambda\ M_0\, e^{-\lambda x} \sin \lambda x$; Max. $V = 0.644\ \lambda\ M_0$ at $x = \pi/4\ \lambda$ $s_1' = -6\ M_x/t^2$; Max. $s_1' = -6\ M_0/t^2$; $s_2' = \nu\ s_1'$ $s_s = V/t$ Hoop stress $s_2 = 2\ \lambda^2\ R\ M_0\, e^{-\lambda x} (\cos \lambda x - \sin \lambda x)/t$; Max. $s_2 = \frac{2\ M_0}{t} \lambda^2\ R$ at end. Radial displacement $= \frac{M_0}{2\ D\ \lambda^2}$; $\theta = M_0/\lambda\ D$ **(Ref. 5, 6)**
	12. Uniform normal shear or pressure V_0 lb. per linear in. of circumference at end	$M_x = \frac{R}{R_2} \frac{1}{\lambda}\ V_0\, e^{-\lambda x} \sin \lambda x$; Max. $M = 0.322\ \frac{R}{R_2} \frac{1}{\lambda}\ V_0$ at $x = \pi/4\ \lambda$; $V_x = \left(\frac{R}{R_2}\right)^{3/2} e^{-\lambda x}\ V_0 (\cos \lambda x - \sin \lambda x)$ $s_1' = 6\ M_x/t^2$; Max. $s_1' = 1.932\ \frac{R}{R_2}\ V_0/\lambda t^2$; $s_s = \frac{V}{t}$ **(Ref. 5, 6)** $s_2' = \frac{6}{t^2}\left\{\nu\ M_x - D\left(1 - \nu^2\right)\frac{\cot \phi}{R_2} \frac{1}{2\ \lambda^2\ D} e^{-\lambda x}\left[\ V_0 (\cos \lambda x + \sin \lambda x)\ \right]\right\}$ Hoop stress $s_2 = -\left(\frac{R^2}{R_2}\right)\frac{2\ V_0}{t} \lambda\, e^{-\lambda x} \cos \lambda x$; Max. $s_2 = -\frac{R^2}{R_2} \frac{2\ V_0}{t} \lambda$ at end Radial displacement $= -\frac{V_0}{2\ D} \sin^2 \phi \left(\frac{1}{\lambda^3} - \frac{1}{\lambda^4} \frac{\nu}{2\ R_2} \cot \phi\right)$; $\theta = -\frac{V_0}{2\ \lambda^2\ D} \sin \phi$ (For hemisphere $\phi = \frac{\pi}{2}$, $R = R_2$, and same formulas apply as for Case 10)
ANY FIGURE OF REVOLUTION	 **13.** Uniform radial moment M_0 in. lb. per linear in. of circumference at end	$M_x = \frac{R}{R_2}\, e^{-\lambda x}\ M_0 \left(\cos \lambda x + \sin \lambda x\right)$; Max. $M = M_0$ at end; $V_x = 2\left(\frac{R}{R_2}\right)^{3/2} e^{-\lambda x}\ \lambda\ M_0 \sin \lambda x$; Max. $V = 0.644\left(\frac{R}{R_2}\right)^{3/2} \lambda\ M_0$ at $x = \pi/4\ \lambda$ $s_1' = -6\ M_x/t^2$; Max. $s_1' = -6\ M_0/t^2$; Hoop stress $s_2 = 2\ \lambda^2\ \frac{R^2}{R_2}\, e^{-\lambda x}\ \frac{M_0}{t}\left(\cos \lambda x - \sin \lambda x\right)$ Max. $s_2 = 2\ \frac{R^2}{R_2}\ \frac{M_0}{t} \lambda^2$ at end. $s_2' = -\frac{6}{t^2}\left\{\nu\ M_x - D\left(1 - \nu^2\right)\frac{\cot \phi}{R_2} \frac{1}{2\ \lambda^2\ D} e^{-\lambda x}\left(2\ \lambda\ M_0 \cos \lambda x\right)\right\}$ Radial displacement $= \frac{M_0}{2\ D\ \lambda^2} \sin \phi$; $\theta = \frac{M_o}{\lambda\ D}$ $s_s = \frac{V}{t}$ (For hemisphere, same formulas apply as for Case 11) **(Ref. 5, 6)**
CYLINDRICAL WITH FLAT HEAD	 **14.** Uniform internal (or external) pressure of p lb. per sq. in.	$M_0 = \left[\frac{p\ R^2\ \lambda^2_2\ D_2}{4\ D_1\ (1 + \nu)} + \frac{2\ p\ R^2\ \lambda_2^3\ E\ t_1\ D_2}{E\ t_2\ (1 - 1/2\ \nu)\ [E\ t_1 + 2\ R\ D_2\ \lambda\ _2^3\ (1 - \nu)]}\right]$ $\div \left[2\ \lambda_2 + \frac{2\ R\ \lambda^2_2\ D_2}{D_1\ (1 + \nu)} - \frac{\lambda_2\ E\ t_1}{E\ t_1 + 2\ D_2\ \lambda\ _2^3\ R\ (1 - \nu)}\right]$ $V_0 = M_0\left(2\ \lambda_2 + \frac{2\ R\ \lambda^2_2\ D_2}{D_1\ (1 + \nu)}\right) - \frac{p\ R^2\ \lambda^2_2\ D_2}{4\ D_1\ (1 + \nu)}$ Here D_1 refers to flat head; D_2 and λ_2 refer to cylinder.

FORM OF VESSEL	MANNER OF LOADING	THIN VESSELS — LOCAL AND DISCONTINUITY STRESSES
 CYLINDRICAL WITH HEMISPHERICAL HEAD	**15.** Uniform internal (or external) pressure of p lb. per sq. in.	$M_0 = p R t_1 \left\{ \frac{\left[c(2-\nu) - (1-\nu) \right] \frac{\sqrt{3(1-\nu^2)}}{12(1-\nu^2)}}{\left[(1-c^2) - \frac{2(1+c^{3/2})(1+c^{3/2})}{1-c^2} \right]} \right\}$ $Q_0 = 2 M_0 \lambda_1 \left(\frac{c^{3/2}+1}{c^2-1} \right)$ where $c = t_1/t_2$ and λ_1 refers to hemispherical head. If $t_1 = t_2$, $M_0 = 0$ and $V_0 = \frac{p}{8\lambda_1}$
		THICK VESSELS — WALL STRESSES
 CYLINDRICAL	**16.** Uniform internal radial pressure p lb. per sq. in. (longitudinal pressure zero or externally balanced)	$s_1 = 0 \quad s_2 = p \frac{a^2(b^2+r^2)}{r^2(b^2-a^2)}$ Max. $s_2 = p \frac{b^2+a^2}{b^2-a^2}$ at inner surface $s_3 = p \frac{a^2(b^2-r^2)}{r^2(b^2-a^2)}$ Max. $s_3 = p$ at inner surface Max. $s_s = p \frac{b^2}{b^2-a^2}$ at inner surface $\Delta a = p \frac{a}{E}\left(\frac{b^2+a^2}{b^2-a^2} + \nu \right) \quad \Delta b = p \frac{b}{E}\left(\frac{2a^2}{b^2-a^2} \right)$
	17. Uniform external radial pressure p lb. per sq. in.	$s_1 = 0 \quad s_2 = -p \frac{b^2(a^2+r^2)}{r^2(b^2-a^2)}$ Max. $s_2 = -p \frac{2b^2}{b^2-a^2}$ at inner surface $s_3 = p \frac{b^2(r^2-a^2)}{r^2(b^2-a^2)}$ Max. $s_3 = p$ at outer surface Max. $s_s = -1/2$ Max. s_2 at inner surface $\Delta a = -p \frac{a}{E}\left(\frac{2b^2}{b^2-a^2} \right) \quad \Delta b = -p \frac{b}{E}\left(\frac{a^2+b^2}{b^2-a^2} - \nu \right)$
	18. Uniform internal pressure p lb. per sq. in. in all directions	$s_1 = p \frac{a^2}{b^2-a^2}$ s_2 and s_3 same as for Case 16 $\Delta a = p \frac{a}{E}\left[\frac{b^2+a^2}{b^2-a^2} - \nu\left(\frac{a^2}{b^2-a^2} - 1 \right) \right] \quad \Delta b = p \frac{b}{E}\left[\frac{a^2}{b^2-a^2}(2-\nu) \right]$
 SPHERICAL	**19.** Uniform internal pressure p lb. per sq. in.	$s_1 = s_2 = p \frac{a^3(b^3+2r^3)}{2r^3(b^3-a^3)}$ Max. s_1 = Max. $s_2 = p \frac{b^3+2a^3}{2(b^3-a^3)}$ at inner surface $s_3 = p \frac{a^3(b^3-r^3)}{r^3(b^3-a^3)}$ Max. $s_3 = p$ at inner surface Max. $s_s = p \frac{3b^3}{4(b^3-a^3)}$ at inner surface $\Delta a = p \frac{a}{E}\left[\frac{b^3+2a^3}{2(b^3-a^3)}(1-\nu) + \nu \right] \quad \Delta b = p \frac{b}{E}\left[\frac{3a^3}{2(b^3-a^3)}(1-\nu) \right]$ **(Ref. 6)**
	20. Uniform external pressure p lb. per sq. in.	$s_1 = s_2 = -p \frac{b^3(a^3+2r^3)}{2r^3(b^3-a^3)}$ Max. s_1 = Max. $s_2 = -p \frac{3b^3}{2(b^3-a^3)}$ at inner surface $s_3 = p \frac{b^3(r^3-a^3)}{r^3(b^3-a^3)}$ Max. $s_3 = p$ at outer surface $\Delta a = -p \frac{a}{E}\left[\frac{3b^3}{2(b^3-a^3)}(1-\nu) \right]$ $\Delta b = -p \frac{b}{E}\left[\frac{a^3+2b^3}{2(b^3-a^3)}(1-\nu) - \nu \right]$ **(Ref. 6)**

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